

Volume

1

INCIDENCE AND POSSIBLE CAUSES OF
FIRES WITHIN COAL MINES OF
THE NOVA SCOTIA COAL FIELDS
AND ON MEASURES THAT CAN BE TAKEN TO
PREVENT SUCH FIRES

STAGE 1
SOCIO-ECONOMIC
IMPACT OF MINE FIRES

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EXECUTIVE SUMMARY

INTRODUCTION

This project was completed by Norwest Resource Consultants Ltd. of Calgary, Alberta. Scientific and technological content of the project was subject to review by a four person Management Committee representing:

Cape Breton Development Corporation (CBDC)

- Mr. R. McLean, Director of Engineering

Department of Labour (Labour Canada)

- Mr. T. Smales, District Manager

Nova Scotia Department of Mines and Energy (NSDME)

- Mr. E. Bain, Manager, Coal Development

Cape Breton Coal Research Laboratory (CBCRL)

- Mr. G. Haslett, CANMET Scientific Authority for the Project

Project work commenced in May 1988. It was done in three stages. The work program for each stage was discussed with the Management Committee and approved before work started.

Draft stage reports were submitted to the Committee and the final report was completed in February 1990.

REPORT CONTENT

Stage I Report

Mine Fire Experience in Sydney Coalfield

Stage I reviews the history of mine fires in the Sydney Coalfield. Six major fire incidents are reviewed, all of which occurred in the years 1973 through 1988.

They are summarized below:

- 1973 No.12 Colliery - a fire which resulted in the closure of the mine.
- 1975 No.26 Colliery - a methane ignition at the face which resulted in the loss of the wall and its mining equipment.
- 1977 Lingan Mine - a methane ignition which resulted in a two week loss of production.
- 1979 No.26 Colliery (12 South Dist.) - a methane ignition which resulted in a five week shut down of a production face.
- 1982 No.26 Colliery - a fire at the No.9 South booster fan causing major damage and resulting in a six-day temporary mine closure.
- 1984 No.26 Colliery - a fire of unknown origin (which may have started at a conveyor) resulted in the permanent closure of the mine and the loss of 1145 jobs.

Minor incidents which occurred between April 1985 through April 1988, were examined; these incidents caused, or were capable of causing, fires underground.

The review clearly showed that conveyors and electrical switchgear were the most common causes of fire in CBDC mines. Since major fires result from the same causes as minor fires, the report concludes that a reduction in the number of minor fire incidents would produce a corresponding reduction in major ones.

Costs of Fires - Direct and Socio Economic

It was found impossible to accurately determine the socio-economic costs of the major fires but the following estimates are given for 1973 - 1988.

Direct costs to CBDC	\$143.5 million
Capital asset replacement	<u>\$289.0 million</u>
 Total Cost to CBDC	 \$432.5 million
 Add total community costs	 <u>\$ 82.3 million</u>
 Total Overall Cost	 \$514.8 million

The long term social effects were very difficult to determine because of lay-offs in neighbouring industries. It is concluded that the social impact was reduced due to:

- . Federal/ Provincial financial "safety nets"; and
- . jobs created by the newly developed Phalen Colliery.

Conclusions and Recommendations

Hypothetical cost projections are used to illustrate the potential for cost saving by effective fire prevention (see Table 6.5). It is shown that, if half the annual cost of mine fires was spent on fire prevention, and it reduced fire costs in the succeeding year by 33%, then, in a 5 year period:

- . fire costs would drop from, \$29.05M to \$5.70M; and
- . fire prevention expenditures could fall by \$11.65 M.

It is recommended that:

- . Improvements continue to be made in the collection of fire cost data and how the fires were extinguished.
- . Loss control personnel develop ways to evaluate the cost/benefit of fire prevention expenditures.
- . Management recognizes and rewards employees for appropriate and effective fire preventative actions.

Stage II Report

Types of Fires

Types of fire and their classification are noted:

- . Oxygen rich and fuel rich fires.
- . Severity of fire.
- . Classification by cause.
- . Classification by material burning and means of ignition.

Mine Visits

Underground visits were made to the CBDC operating mines Langan, Phalen and Prince, between August 16th and August 24th, 1988; technical discussions were held with Management and Engineering Staff. A review of the visits notes the following:

- . CBDC's ample provision and maintenance of fire fighting equipment.
- . The limited fire fighting training provided.
- . The need for fire prevention improvements on conveyors.
- . The need for improvement in installation and maintenance - especially of electrical equipment.

- . The need to improve mine tidyness.
- . CBDC's program for replacing combustibile materials.
- . The scheme for reversal of air flow in intake, conveyor access slopes.

Prevention of Fires

Recommendations are made to reduce the incidence of fires; topics addressed include:

- . Longwall advancing vs retreating mining methods.
- . Belt conveyor systems.
- . Roadway fires and the replacement of wood chocks by cement/anhydrite inert materials and treating wood to make it fire resistant.
- . Ignition of methane by incendive sparking.
- . Electrically caused fires.

Monitoring and Detection of Fires

The value of human senses for fire detection and the use of heat/fire detecting portable instruments are discussed. Remote environmental monitoring by the "Tube Bundle" system is compared to the electronic transducer, remote sensing head system. The importance of the Central Control Room for environmental control, evacuation and fire fighting is described.

Direct Methods of Fire Combat

Direct fire fighting measures are described from small fires to building fire seals. The importance of early fire detection and immediate appropriate action are emphasized.

Also discussed are:

- . Pre-preparation of protective measures, (i.e. automatic extinguishers, fire barriers and fire seal sites).
- . Problems and dangers of smoke and products of combustion.
- . Dealing with spontaneous heating.
- . Sealing-off and use of rescue teams.
- . Fire fighting policies and organization.

Evacuation of the Mine

The evacuation problems at CBDC mines are noted and also evacuation problems in general. The report discusses:

- . Escape routes, the use of manriding facilities and self rescuers; it recommends the provision of replacement, oxygen, self rescuers on long escape routes.
- . Refuge chambers, their use and strategic location.
- . Communication and warnings to evacuate.
- . Manriding facilities up the main access slopes - speed of travel and possible use of protective manriding cars.
- . Behaviour of persons during emergency conditions, especially in smoke.

Indirect Methods of Fire Containment

The use of inert gases and "Inerting" methods of fire suppression are discussed including:

- . Suppliers of gas;
- . Storing and handling gas;
- . Application of inert gas.

Sealing off fires describes:

- . Types of stoppings and their designs.
- . Working conditions at stoppings and worker protective measures.

Mine Ventilation and Fires

The effects of hot air and gases are described especially phenomena related to buoyancy, air reversal, smoke migration and "Thermal Constriction" of air flow. The advantages and dangers of ventilation changes during fire fighting are noted as well as the application of inflatable stoppings.

Concerns arising from the use of a "bleeder" return airway from retreating longwalls are explained, particularly its limitation on methane drainage schemes and the possible loss of air flow control.

The importance of sampling, analysis of samples and rapid interpretation of results are discussed and also mine fire gases and the development of explosive and extinctive atmospheres.

The report recommends that CBDC reviews its sampling, analysis and interpretations procedures. Comment is made on the value of trained samplers and computer interpretation of results.

Conclusions and Recommendations

Stage II concludes that CBDC efforts have been devoted mainly towards:

- . fire detection;
 - . fire combat; and
 - . evacuation,
- activities which follow the outbreak of fire. It is recommended that attention now turns to Fire Prevention.

Areas where fire prevention programs should be concentrated, are given as:

- . Conveyors: - improved transfer station designs
- improved performance of idler rollers
- . Maintenance: - improved standards for:
 - installations
 - inspections
 - repairs and maintenance work
- . Operational: - greater care of trailing cables
- improved worker responsibility through training
- . Training: - the human element is recognized as a key feature of effective fire prevention
- a vigorous fire prevention program, should be integrated with fire fighting training
- training to include hands-on, job-site practices.

A suggested approach is for CBDC to set up a small executive group to oversee the development of a fire training program which will cover:

- . worker responsibility and work-site practices;
- . detection and immediate action; and
- . the extinguishment of fires.

The group to be responsible for:

- . structuring of the training scheme and its courses;
- . selection and training of instructors; and
- . ensuring that the program includes realistic job-site practices.

It is recognized that there will be a need for training facilities. Existing installations can be adapted or a special training gallery might be constructed at a suitable site. Cost estimates for a special gallery will help CBDC to decide how training facilities can best be provided.

Stage III Report

Introduction

Stage III addresses the use of computers when fighting fire, and lists programs available. It reviews foreign research facilities and their availability for research into fire fighting and fire prevention. Possibilities for research relevant to the Sydney Coalfield are discussed.

The report ends with the description of a specially built fire training facility, its capital and operating costs and an example of a fire training program.

Computers

The application of computers is discussed, particularly their use for:

- . predicting the effects of fire on mine ventilation; and
- . predicting explosibility of mine atmospheres.

A list of mine fire/ventilation computer programs and suppliers is provided.

The importance of accurate atmosphere sampling is noted and "Rules" for sampling are quoted.

It is recommended that CBDC reviews:

- . the adequacy of its facilities and procedures for large volume, emergency sampling; and
- . the availability of trained samplers for round-the-clock sampling in an emergency.

Foreign Research Facilities

A brief outline of non-Canadian research facilities is given for establishments in:

United States
United Kingdom
France
Germany (FDR)
Australia
Poland

Most are willing to accept research contracts at costs negotiated for each specific project.

Research and Development Related to Sydney Coalfield

It is concluded that current development and improvement needs for the Sydney Coalfield are within the scope and capability of CBDC mining engineering staff.

It is recommended that CBDC's initial investigations into obtaining anhydrite packing material, from identified local sources, be continued.

Further investigation to address::

- . funding;
- . sources and quality of material;
- . patent constraints of current foreign suppliers;
- . mineral treatment needed to get a suitable product;
- . sample testing; and
- . economics of production.

This work can be done by Canadian personnel in Canadian facilities. Research work in foreign facilities is not required at this time.

Fire Training Facility

The need for fire training facilities is noted - either making use of existing installations or by building a special training gallery.

Designs are provided for a training gallery which has:

- . an outdoor practice area;
- . indoor practice area;and
- . indoor, simulated, mine tunnels and faces including a "hot and humid" chamber.

Gallery equipment and services are described as well as alternative ventilation circuits that can be produced.

Estimated capital costs for the installation are:

For the building	\$1,848,000
Access and parking	65,300
Furnishings and fittings	165,700
Training equipment & initial supplies	<u>\$ 39,800</u>
Total Cost (incl. contingency provision)	\$2,118,800

Estimated operating costs in the first year are \$416,820, falling to \$409,540 per annum by the fifth year.

Examples of fire training courses and exercises are given.

RÉSUMÉ

INTRODUCTION

Ce projet a été exécuté par Norwest Resource Consultants Ltd. de Calgary, Alberta. Le contenu scientifique et technologique du projet a été révisé par un Comité de gestion formé de quatre personnes représentant:

Société de développement du Cap-Breton (SDCB)

- M. R. McLean, directeur de l'ingénierie

Ministère du Travail (Travail Canada)

- M. T. Smales, directeur régional

Nova Scotia Department of Mines and Energy (NSDME)

- M. E. Bain, Directeur, mise en valeur du charbon

Laboratoire de recherches de charbon du Cap-Breton

- M. G. Haslett, scientifique autorisé par CANMET

Ce projet a débuté en mai 1988. Le travail a été fait en trois phases distinctes. Le programme de chaque phase a été discuté avec le Comité de gestion et a été approuvé avant que le travail commence.

Des rapports préliminaires sur chaque phase ont été soumis au comité et le rapport final a été terminé en février 1990.

RAPPORT

Rapport: Phase I

L'historique des incendies de mines du gisement houiller de Sydney

Durant la première phase, l'historique des incendies de mines du gisement houiller de Sydney a été fait. Six incendies majeurs ont été examinés, ces derniers ayant survenu durant la période allant de 1973 à 1988.

En voici le sommaire:

1973: Mine No. 12 - un incendie ayant comme résultat la fermeture de la mine.

1975: Mine No. 26 - une inflammation du grisou sur le front d'abattage ayant comme résultat la perte de la paroi et de l'équipement s'y trouvant.

1977: Mine Lingan - une inflammation du grisou ayant comme résultat la perte de deux semaines de production.

1979: Mine No. 26 (Région du Sud, no. 12) - une inflammation du grisou ayant comme résultat la fermeture du front de taille pour cinq semaines.

1982: Mine No. 26 (Région du Sud, no. 9) incendie d'un ventilateur secondaire causant des dommages considérables et ayant comme résultat une fermeture temporaire de six jours.

1984: Mine No 26 - un incendie d'origine inconnue (pouvant avoir commencé à un convoyeur) ayant comme résultat la fermeture permanente de la mine et la perte de 1145 emplois.

De plus, des incidents mineurs ayant eu lieu entre avril 1985 et avril 1988 ont été examinés; ces incidents ont causé ou étaient capables de causer des incendies souterrains.

L'examen de ces incidents démontre clairement que les convoyeurs et les interrupteurs électriques étaient les causes d'incendie les plus communes dans les mines de la SDCB. Puisque les incendies importants proviennent des mêmes causes que les incendies mineurs, ce rapport conclut qu'une réduction dans le nombre d'incendies mineurs produirait une réduction correspondante d'incendies majeurs.

Coûts des incendies - Coûts directs et coûts socio-économiques

Il n'a pas été possible de déterminer avec précision les coûts socio-économiques des incendies majeurs mais les estimations suivantes sont données pour la période allant de 1973 à 1988.

Coûts directs pour la SDCB	\$143.5 million
Remplacement de l'actif immobilisé	<u>\$289.0 million</u>
Coût total pour la SDCB	\$432.5 million
Plus les coûts totaux de la communauté	<u>\$82.3 million</u>
Grand total	\$514.8 million

Les coûts sociaux à long terme ont été très difficiles à déterminer à cause du licenciement de la main-d'oeuvre dans d'autres industries de la région. Il a été conclu que les répercussions sociales ont été réduites par suite de:

- contributions financières fédérales/provinciales; et de
- création d'emplois par la nouvelle mine Phalen.

Conclusions et recommandations

Des projections hypothétiques des coûts ont été utilisées pour illustrer les épargnes possibles que la prévention des incendies pourrait offrir (voir table 6.5) Il est démontré que si la moitié du coût annuel des incendies de mines était appliquée à la prévention des incendies, produisant ainsi une réduction de 33% des coûts durant l'année suivante, les conséquences, pour une période de cinq ans, seraient:

- une réduction des coûts d'incendie allant de \$29.05M à \$5.70M;
- et une diminution des frais de prévention des incendies de \$11.65M.

Il est recommandé que:

- des améliorations continuent à se faire dans la collection des données sur les coûts des incendies et sur la manière de les éteindre.
- le personnel chargé du contrôle des pertes détermine des manières d'évaluer les coûts/bénéfices des frais de préventions des incendies.
- la gestion reconnaisse et récompense les employés travaillant à la prévention des incendies d'une manière appropriée et effective.

Rapport: Phase II

Genres d'incendies

Les genres d'incendies et leur classification sont mentionnés:

- incendies riches en oxygène ou en combustible;
- gravité de l'incendie;
- classification selon la cause;
- classification selon le matériel brûlé et le moyen d'inflammation.

Visites des mines

Les mines Lingan, Phalen et Prince de la SDCB ont été l'objet de visites souterraines entre le 16 et le 24 août 1988; des discussions techniques ont eu lieu avec le personnel de gestion et d'ingénierie. Les remarques suivantes ont été faites:

- la SDCB possède du matériel d'incendie en grande quantité et bien entretenu;
- l'entraînement disponible de lutte contre les incendies est limité;
- des améliorations sur les convoyeurs s'avèrent nécessaires;
- des améliorations sont aussi nécessaires dans les installations et l'entretien en général et particulièrement dans l'équipement électrique;
- le bon ordre de la mine doit être amélioré;
- la SDCB possède un programme visant à remplacer les matériaux combustibles;
- la SDCB possède un système de renversement du débit d'air par des prises d'air, dans les pentes des convoyeurs.

Prévention des incendies

Des recommandations sont faites pour réduire la fréquence des incendies; les sujets mentionnés incluent:

- l'exploitation par taille avançante chassante contre l'exploitation par longue taille rabattante;
- des systèmes de convoyeurs;
- des incendies de galeries et le remplacement des piles de bois par des matériaux inertes de ciment/anhydrite et en utilisant du bois imprégné et rendu résistant aux flammes;
- inflammation du grisou par des étincelles inflammatoires;
- des feux d'origine électrique.

Surveillance et détection des incendies

Il est ici question de l'importance d'utiliser les cinq sens pour la détection des incendies et de l'utilisation d'instruments portatifs capables de détecter des feux ou une augmentation de chaleur. Une surveillance de l'environnement par le système de télécommande "Tube Bundle" est comparée à celle que donne un système de détecteur télécommandé utilisant un transmetteur électronique. Il est aussi question de l'importance d'une Salle de contrôle central pour le contrôle de l'environnement, l'évacuation et la lutte contre les incendies.

Méthodes directes pour combattre un incendie

Il est ici question de méthodes directes pour combattre tous genres d'incendie allant de la maîtrise de petits feux jusqu'à la construction de barrages étanches. L'accent est mis sur l'importance de détecter un incendie dans ses premiers temps et d'intervenir immédiatement et d'une manière appropriée.

On y mentionne aussi:

- la préparation de longue main de mesures de protection, (par exemple, extincteurs automatiques, zones d'extinction et barrages étanches);
- les problèmes et les dangers de la fumée et de la combustion de certains produits;
- la manière de réagir à l'échauffement spontané;
- l'isolement d'un conduit de mine et l'utilisation des équipes de secours;
- une organisation et des méthodes de lutte contre l'incendie.

Evacuation de la mine

Les problèmes d'évacuation dans les mines la SDCB ainsi que les problèmes d'évacuation en général sont ici examinés. Le rapport mentionne:

- les sorties de secours, l'emploi des wagons pour le transport des mineurs et l'utilisation des appareils auto-protecteurs; le rapport recommande la prise de dispositions nécessaires pour le remplacement des appareils auto-protecteurs pour les sorties de secours de longue distance;
- les lieux de refuge (niches), leur utilisation et leur emplacement stratégique;
- les communications et les signaux d'évacuation;
- les installations de wagons le long des principales pentes - vitesse de déplacement et l'utilisation possible de wagons fermés;
- la manière de se conduire dans une situation d'urgence, surtout en cas de fumée.

Méthodes indirectes de contenir les flammes

On discute ici de l'emploi de gaz inertes et de méthodes d'inertion pour éteindre un incendie:

- fournisseurs de gaz;
- manipulation et storage des gaz;
- utilisation des gaz inertes.

La section sur l'isolement d'un conduit de mine porte sur:

- différentes sortes de barrages et leur planification;

- conditions de travail aux endroits prévus pour l'isolement d'un incendie et mesures de protection à prendre pour les mineurs.

Incendies et ventilation des mines

On discute ici des effets de l'air chaud et des gaz, spécialement de phénomènes se rapportant à la flottabilité, au renversement du débit d'air, à la propagation de la fumée et à la "constriction thermique" du débit d'air. Les avantages et les dangers dans les changements de la ventilation durant la lutte contre un incendie sont indiqués ainsi que l'utilisation des barrages gonflables.

On explique aussi les difficultés provenant de l'utilisation des fuites d'air dites "bleeder" à partir des longues tailles rabattantes, surtout de leur limitation quant aux systèmes de captage du grisou et à la perte possible du contrôle du débit d'air.

On mentionne l'importance de prendre des échantillons d'atmosphères, d'en faire des analyses et d'en interpréter rapidement les résultats. On parle aussi des gaz associés aux incendies de mines et du développement d'atmosphères explosives et d'atmosphères non-propices à la combustion.

Le rapport recommande que la SDCB réexamine ses procédés d'échantillonnage, d'analyse et d'interprétation. On y fait des commentaires sur la valeur des échantillonneurs bien entraînés et des résultats interprétés par des ordinateurs.

Conclusions et recommandations

Le rapport concernant la Phase II conclut que l'attention de la SDCB s'est surtout porté sur:

- la détection des incendies;
- la lutte contre l'incendie;
- l'évacuation;

Toutes ces choses prennent place après qu'un incendie a déjà commencé. Le rapport recommande que l'attention devrait maintenant se porter sur la prévention des incendies.

Les programmes de préventions pourraient se concentrer sur:

- les convoyeurs: - points de transfert améliorés
- meilleure performance des rouleaux
- l'entretien: - meilleures normes pour les
- installations
- inspections
- réparations et travail d'entretien
- les opérations: - meilleur soin des câbles traïnants
- plus de responsabilité de la part des
- mineurs
- l'entraînement: - le facteur humain est reconnu comme étant
- le principal élément pour une prévention
- effective
- un programme intensif de prévention
- devrait être intégré dans l'entraînement
- contre les incendies
- l'entraînement devrait inclure des

pratiques sur place avec le matériel
d'incendie.

Il est suggéré que la SDCB forme un petit groupe de gestion pour surveiller l'élaboration d'un programme d'entraînement qui couvrirait:

- responsabilité des travailleurs et pratiques sur place;
- détection et action immédiate;
- extinction des incendies.

Ce groupe serait responsable pour:

- la composition de l'équipe d'entraînement et les cours offerts;
- le choix et l'entraînement des instructeurs;
- s'assurer que le programme comprenne des pratiques sur place.

Un centre d'entraînement s'avèrerait nécessaire. Les installations déjà existantes pourraient être adaptées ou une galerie spéciale pourrait être construite à un endroit convenable. Une estimation des coûts d'une galerie aideront la SDCB à décider comment l'entraînement pourrait être assuré de la meilleure manière possible.

Rapport: Phase III

Introduction

Dans cette phase, on étudie l'emploi des ordinateurs dans la lutte contre l'incendie et on donne des listes de programmes

disponibles. On passe en revue les installations de recherches situées à l'étranger et la possibilité de les utiliser pour des recherches concernant la lutte contre les incendies et leur prévention. Les possibilités de faire des recherches pertinentes au gisement houiller de Sydney sont ici discutées.

Le rapport se termine avec la description d'une galerie bâtie spécialement pour l'entraînement contre l'incendie, les coûts en capital et en frais de fonctionnement ainsi qu'un exemple d'un programme d'entraînement.

Ordinateurs

On discute ici de l'utilisation des ordinateurs, en particulier de leur emploi pour:

- prédire les effets des incendies de mines sur la ventilation des mines;
- et prédire l'explosivité des atmosphères des mines.

Cette section inclut une liste de programmes en informatique concernant les incendies de mines et la ventilation ainsi qu'une liste des fournisseurs de programmes.

On discute aussi de l'importance de prendre des échantillons d'une manière précise et on cite les "Règles à suivre" pour l'échantillonnage.

Il est recommandé que la SDCB s'assure que:

- ses installations et ses procédés soient adéquats pour l'échantillonnage en grande quantité et pour l'échantillonnage d'urgence;

- des échantillonneurs bien entraînés soient disponibles pour faire de l'échantillonnage vingt-quatre heures sur vingt-quatre en cas d'urgence.

Installations de recherches à l'étranger

On donne ici une brève vue d'ensemble des installations de recherches non-canadiennes. On parle des installations:

aux États-Unis,

au Royaume-Uni

en France

en Allemagne

en Australie

en Pologne

La plupart de ces installations accepteraient de faire de la recherche sous contrat à un coût négociable pour chaque spécifique projet.

Études et recherches relatives au gisement houiller de Sydney

En ce qui concerne le gisement houiller de Sydney, les besoins actuels en programmes et en améliorations sont dans le domaine des compétences du personnel de l'ingénierie de la SDCB.

Il est recommandé que la SDCB continue sa recherche pour l'obtention d'un matériel de remplissage anhydrite à partir de sources locales connues.

Autres sujets à rechercher:

- fonds disponibles
- sources et qualité des matériaux;
- brevets concernant le matériel des fournisseurs étrangers actuels;
- traitement des minéraux afin d'obtenir un produit adéquat;
- prise d'échantillons;
- rentabilité de production.

Ces recherches peuvent être faites par des canadiens ici même au Canada. Le travail de recherche à l'étranger n'est pas nécessaire présentement.

Centre d'entraînement pour la lutte contre l'incendie

On discute de la nécessité d'un centre d'entraînement, soit en utilisant les installations existantes soit en construisant une galerie d'entraînement.

Des modèles pour une telle galerie sont inclus:

Cette installation comprendrait:

- un endroit pour des pratiques à l'extérieur;
- un endroit pour des pratiques à l'intérieur;
- des galeries comprenant un front de taille et un lieu "chaud et humide".

L'équipement de la galerie et les services sont décrits ainsi que des systèmes alternatifs de ventilation.

Estimation des coûts d'installation:

Édifice	\$1, 848,000
Voies d'accès et aire de stationnement	65,300
Ameublement et équipement	165,700
Équipement d'entraînement & provisions initiales	<u>39,800</u>
Coût total (y compris les provisions d'urgence)	\$2,118,800

Estimation des frais de fonctionnement pour la première année:

\$416,820

se réduisant à \$409,540 par année durant la cinquième année.

Des exemples de cours d'entraînement et d'exercices de lutte contre l'incendie sont inclus dans cette section.

1.0 INTRODUCTION
1.1 SCOPE OF WORK
1.1.1 For the Complete Study

As the title of the study suggests, the Consultants are required to report on the incidence and possible causes of fires within the coal mines of the Nova Scotia Coalfields and on measures that can be taken to prevent such fires.

The year-long study is divided into three stages:

- Stage 1 - A review of the Socio-economic impact of mine fires.
 (this report)
- Stage 2 - The causes of mine fires and their prevention.
- Stage 3 - The costs and benefits of Research and Development
 Programmes and/or a fire gallery test installation
 to research and develop methods whereby the
 incidence of fires and their effects can be
 minimized.

1.1.2 Stage 1 - Statement of Work

The statement of work in the contract for Stage 1 is as follows:

"This review must compile a case history of mine fires within the Sydney Coalfield and their impact on the local communities. The review must take into consideration and report on the socio-economic impacts of such fires and quantify the cost-benefits to be gained from their exclusion in terms of: cost of compensation, costs of litigation, loss of employment opportunities and wages, loss of taxes to local governments, capital losses and loss of coal reserves."

It includes minor incidents at the new Donkin tunnels as well as incidents at the three major producing mines, The Prince Colliery, The Lingan Colliery and The Phalen Colliery.

Following agreement by the Scientific Authority for the Project, the investigation will go back a period of 15 years, to the major incident at No. 12 Colliery in 1973. In total six major incidents have been investigated. It was found that minor incidents have only been recorded in moderate detail since 1985. Earlier than 1985, the records were not sufficiently detailed for meaningful conclusions to be drawn, particularly with regard to the costs incurred by the fires.

The work commenced by reading:

- . background reports on the Coal Industry of Cape Breton;
- . the findings of Commissions which reported on major mine incidents and, reports on general industrial, social and political investigations such as that by Dr. D.R. Donald in 1966.

An examination was made of the effects and total costs incurred by underground coal mine fires, during the 15 years since 1973, in terms of: lives, equipment, coal reserves, tax bases, human values, population changes, changes in job types, training and management.

1.2 OBJECTIVES

These can be summarized as follows:

- . Collect information on mine fires in the Sydney Coalfield over the last 15 years.
- . Assess, in 1988 dollars, how much these fires have cost the industry and the community.

. Assess the cost-benefit of eliminating underground fires.

1.3 TECHNICAL APPROACH

By reading the reports of the six incidents and talking with people involved in them, it has been possible to form a fairly good understanding of the events which took place in the mine and in the community.

Factual information has been obtained as far as possible. This has often been in the preferred form of items, such as quantities of material, numbers of people, etc. so that a value in today's dollars can be put on them. If only dollar values at the time were available, an escalation formula from Stats-Can has been used to bring them to a 1988 dollar value.

Mine plans were obtained and marked up to show the position of the workings at the time of the major incidents.

Records from Federal, Provincial, County and Municipal governments were used to generate many of the tables used in the report.

1.4 ACKNOWLEDGEMENTS

Special thanks are due to the following persons who greatly assisted in collecting the information required for this study:
Cape Breton Development Corporation Departments

Mine Engineering
Marketing
Mine Controller
Lingan Phalen Management
Auditors
Accounting

Industrial Relations
Compensation
Pensions and Benefits
Public Relations
Central Records
Occupational Health
Safety
Fire Prevention
Labour Canada Regional Office, Sydney
Canmet Regional Office, Sydney
Nova Scotia Department of Mines and Energy
Deputy Minister
Library
Economic Centre
Department of Employment and Immigration, Sydney
Department of Employment and Immigration, Glace Bay
Statscan - Halifax
Cape Breton Library
Workmans Compensation Board, Claims Division
Town of Glace Bay, Tax Department
Town of North Sydney, Administration
Royal Bank, Sydney
Royal Bank, Glace Bay

2.0 HISTORICAL BACKGROUND

The Patching Commission of Inquiry that investigated the 1973 fire and explosion in No. 12 Colliery, provided the following background:

"Coal mining on Cape Breton Island has a long and varied history. The first recorded mining of coal in North America occurred on Cape Breton Island in 1720 when the French started mining near Port Morien. This was to supply the fuel requirements of the French fortress being built at Louisbourg.

However, large scale development did not occur until the mid to late 1800's when coal for steamships was in great demand. The proximity of Cape Breton Island to the North Atlantic trade routes provided a natural supply base for coal for steamships. At the turn of the century, a market also developed for metallurgical use of Sydney coals. The economy of this area thus became very dependent on the coal industry and for the most part has remained so to this day."

"The development and problems of the coal industry in Cape Breton have been well described in reports of several Commissions, the most recent being the reports of Rand in 1960 and Donald in 1966."

"With the decline of markets after the First World War, the coal industry on Cape Breton Island began a long-term period of decline which continued into the 1970's. Since the mid 1920's subventions, subsidies, loans and other forms of assistance have been made by government authorities. By the mid 1960's subventions and subsidies were rapidly escalating. Moreover at this time the company which operated the four major mines in the

Sydney area indicated to the Federal Government that it was interested in getting out of the business of operating unprofitable coal mines."

"In 1965 the Government of Canada appointed Dr. J.R. Donald to investigate and make recommendation on the Cape Breton coal situation. Following the Donald Report, Parliament of Canada established a Crown Corporation (Cape Breton Development Corporation Act (CBDC), Chapter 6 of the Statutes of 1967, assented to in July, 1967) to acquire and operate the coal mining assets of the Nova Scotia subsidiaries of the Dominion Steel and Coal Corporation Ltd. (DOSCO). Effective April 1, 1968 the Cape Breton Development Corporation (Devco) took control of the operations."

"The original plan of the Corporation was to phase out the existing four coal mines in a 15 year period (the Corporation had federal government approval to develop a new mine at Lingan and indicated its desire to do so in October 1968), reduce the work force, and develop alternate forms of employment through industrial development on the island. The reduction of coal mining operations began, and in 1969 No. 20 Mine at Glace Bay was closed. The other three mines continued to operate, initial development of Lingan began in 1969, and Devco pursued its industrial development objective. The existing mines continued to deteriorate and operating losses continued to mount."

"However, with a change of management in 1972 and an improving outlook for coal in the energy market, it appeared that there was a future for Cape Breton coal and that a new capital infusion program was needed to modernize the mining capability.

Thereafter not only was industrial development to be stressed but also coal mining. The new mine at Lingan was to be accelerated into production and two of the existing three mines were to be rehabilitated."

"Since an emphasis was to be placed on metallurgical coal markets, a new preparation plant would also be needed which would be specifically designed to improve the coking quality of Sydney coals by lowering their sulphur content."

"In March of 1973 the Corporation suffered a setback in its program of rehabilitation when the No. 12 Mine at New Waterford was lost after an underground explosion and fire."

After the closure of No. 12 Colliery, output from the Corporation dropped to about 1 million tonnes per year. No. 20 Colliery in Glace Bay had been closed due to exhaustion of reserves and high costs. On the north side, The Princess Mine was replaced by a new Prince Mine in 1975. The Lingan Mine opened in the early seventies and, together with the Princess Mine, they were able to absorb all the men from No. 12 Colliery when it closed down.

In the late seventies, partly due to the oil crises and a policy to burn expensive coal rather than oil for some power plants, output in the corporation rose to about 2.5 million tonnes per year. More modern equipment was purchased for the mines, but productivity still did not rise above 5 tonnes per manshift. A major strike lasting almost 3 months occurred in 1981.

In fiscal year 1984, 2.8 million tonnes of coal were produced with a productivity of almost 7 tonnes per manshift.

Plans were made to open a new mine for thermal coal, The Donkin - Morien, to the south of No. 26 Colliery. This reserve is completely under the sea bed. Rock tunnels were driven down from the surface to access the main seam. The main seam is a lower value coal than that found in the seams further to the north.

The high hopes for large coal markets of the early eighties faded as world coal surpluses developed, oil prices eased and, inevitably, coal prices fell. Against this background, there was another major fire resulting in the closure of No. 26 Colliery. Within two months, approval had been given by the Federal Government to start work developing the new Phalen Slopes to access the area of coal beneath the Lingan Colliery. By 1987, when Phalen commenced production all the men from No. 26 Colliery were either employed or had retired.

Table 2-1 shows some of the principle statistics of the operations of the Cape Breton Development Corporation.

Table 2-1
STATISTICAL SUMMARY - CBDC

Fiscal Year	Workmen's Compens. \$Millions Actual \$	Lost Time Accid k days	InjurA Days Lost	InjurB Per Mil. Hrs. wkd.	Prody. Tonnes/ Shift	Aver.C Price/ Tonne	Corporation Presidents
1973		37.7		0.9	2.1	12.23	1973 Kent
74	NA	40.5	350	0.9	2.3	13.33	1974 Kent
75	NA	37.3	324	1.5	2.2	18.66	1975 Kent
76	NA	47.7	368	1.8	3.4	23.39	1976 Matheson
77	NA	57.1	345	1.9	3.5	22.78	1977 Matheson
78	6.1	66.7	386	2.3	4.1	30.86	1978 Matheson
79	6.4	74.3	380	2.4	4.2	35.87	1979 Rankine
1980	6.9	88.4	440	2.1	3.7	38.44	1980 Rankine
81	6.9	58.5	439	2.3	4.2	43.15	1981 Rankine
82	9.2	58.2	401	2.2	4.7	55.80	1982 Rankine
83	13.1	60.6	400	2.5	5.3	59.89	1983 Rankine
84	14.3	35.7	352	2.8	6.9	51.10	1984 Shannon
85	11.8	50.6	226	2.4	7.1	69.98	1985 Rance
86	11.7	40.1	201	2.3	5.9	68.90	1986 Rance
87	11.3	37.1	139	2.6	6.2	67.87	1987 Rance
88	9.9			3.3	7.3	67.87	1988 McNeil

- A - All operations
B - Disabling injuries per million hours
C - Coal pricing in terms of average revenue price/tonne
NSPC - F.O.B. their site; overseas - F.O.B. - Sydney

3.0 MAJOR INCIDENTS

3.1 INTRODUCTION

Six major fire incidents, which occurred in the Sydney Coalfield since 1973, have been selected for examination in some detail. They are -

- . Fire and Closure of No. 12 Colliery in March 1973
- . Methane Ignition on No. 11 South wall, No. 26 Colliery in June 1975
- . Methane Ignition in No.4 East tail gate, Lingan Colliery in 1977
- . Explosion on No. 12 South face, No. 26 Colliery in February 1979
- . Fire at No. 9 South Booster Fan at No. 26 Colliery in October 1982
- . Fire in the Main Deeps at No. 26 Colliery in April 1984 resulting in closure of the Colliery.

Table No. 3-1 summarizes these incidents. A description of each incident follows, with particular reference to the causes, and possible future preventative measures.

3.2 FIRE AND CLOSURE AT NO. 12 COLLIERY, 1973

The fire occurred on the night shift of 3 March 1973, following an extensive derailment and collision of mine cars on the main haulage.

One hundred and nine men safely reached the surface of the mine. One man apparently became separated from his companions and is assumed to have died by being overcome by fumes or carbon monoxide. A senior mining engineer of the Corporation also died underground while investigating the accident. His death was presumed to have been the result of a heart attack.

A decision was made to seal off the mine at each of the eight surface entrances. This was accomplished by the following day and the main fans were shut off. Three weeks later evidence of an underground explosion was noticed indicating that oxygen was still entering the sealed off mine. Improvements to the seals were made and later analyses of samples from behind the seals showed that an extinctive atmosphere was developing satisfactorily.

Assistance was given by experienced staff from the National Coal Board, the U.S. Bureau of Mines and the Nova Scotia Department of Mines.

Six weeks after the accident the Rescue Teams, Provincial Department of Mines' drill rig and staff, and many of the local staff and men were disbanded.

All the miners were re-deployed to jobs in the neighbouring collieries.

A Commission of Enquiry was later conducted by Mr. Tom Patching.

It was the practice to haul aluminum mine cars, each containing 3 tonnes of coal, up the 2300 m main deep in trips of 18 cars. The main deep haulage, (gradient about 10 degrees) was equipped with a direct rope haulage, powered by an 1800 hp hoist. It was reported that power was lost on the hoist while raising a trip of cars; the brakes were applied and it was assumed that the cars ran back and jerked the rope with such violence that it broke. This allowed the trip to continue running down the slope until it smashed in a derailment producing dust and incendive, frictional sparking.

The capacity of such a haulage system is limited. They are no longer used for coal haulage. Conveyors have replaced them in all the Cape Breton mines ruling out a re-occurrence. However, men and materials are still hauled in and out of the mines using this direct rope system or sometimes a system using endless ropes onto which the supply cars are clipped or bolted. The section on minor incidents indicates that the third most common incident occurs on wire rope haulages.

3.3 IGNITION ON No. 11 SOUTH FACE, No. 26 COLLIERY,
19 JUNE 1975

No. 11 South was an advancing longwall face, equipped with a double drum ranging arm shearer. At the time of the incident the machine was advancing up the face towards the top level (return airway) with the upper drum leading. It appeared that there was a sandstone intrusion in the seam which, when struck by the picks of the shearer drum, caused a spark and an ignition. Methane burned on the face and flame crept along the roof of the face to the tail gate where methane continued to burn. Later a methane drainage borehole in the tail gate caught fire.

Attempts to fight the fire with extinguishers and water, were unsuccessful and preparations were therefore made to seal off the district. Sealing was completed some 12 hours after the emergency.

Three weeks after the incident, methane was still burning and attempts were made to extinguish the flame using 228 tonnes of liquid carbon dioxide over a seven day period. It was possible to enter the sealed off area through doors in the stoppings and it was determined that the fire was out.

All men had been evacuated from the mine and mining operations ceased for a period of 5 weeks. After that time, it was deemed safe to produce coal from 11 North face. 750 men were called back to work.

On October 4th, a rescue team passed through the top level stopping, followed by entry to the bottom level. A methane rich atmosphere at 40°C (103°F) was found.

On November 5th hot air was discovered issuing from the mouth of the 11 South material road. On examination, the floor of the roadway was found to have a temperature over 50°C (120°F) and further inbye was even greater. A decision was made to re-seal the entrance to the section.

Normal operations were finally resumed when 12 North face was prepared for production and started up in January 1976, 7 months after the first fire.

Examinations at the incident site, led to the discovery of cutter picks which had been melted by the heat and a conclusion that ventilation quantities had been insufficient.

Mr. Keith Eaton conducted a Commission of Enquiry and submitted a report dated 9 March 1976. Wayne Leblanc of CBDC wrote a paper on the incident.

Many recommendations were made by the Commission: one of them was the enforcement of the recommendations of the Patching report of 1973. It was also recommended that methane gas detection methods should be improved.

Other recommendations were:

- . ventilation quantities to be planned and checked;
- . installation of a continuous methane monitoring at the return end of each longwall face using an instrument which would give an audible warning and cut off the power when methane concentration reached a dangerous level;
- . use of methanometers with probes for use in locations where access is difficult;
- . installation of venturi drums on all shearers;
- . closer attention to replacing worn shearer picks.

3.4 IGNITION AT NO. 4 EAST TAIL GATE, LINGAN COLLIERY
6 JUNE 1977

An ignition of methane occurred at a back brushing of the tail gate of No. 4 East, advancing longwall face. The flame continued to burn for about one hour, hovering in the roof behind cover boards and over the steel arches. The ignition of the gas was probably due to shotfiring.

Attempts to extinguish the flames with fire extinguishers and water were unsuccessful. Suddenly the flame went out by itself. This led to the conclusion that the gas source had been a methane blower which had gradually become exhausted. However so much water had been applied that the face was not able to be worked until the section had dried out two weeks later.

In the absence of more detailed information it has been assumed, for the purpose of cost estimates, that some water damage was sustained by cables and electrical switchgear.

After this incident the following equipment was introduced:

- . water barriers, water sprays and dust barriers
- . Infra red heat detectors for examining conveyor idlers and cable couplers

3.5 EXPLOSION AT NO. 12 SOUTH, NO. 26 COLLIERY,
 24 FEBRUARY 1979

The explosion occurred on the No. 12 South advancing longwall face near the tailgate end. While cutting the last three feet of coal at the top of the face, the leading drum of the shearer was lowered some seven inches into the quartzitic sandstone floor of the seam.

This produced frictional sparking in the presence of higher than normal percentages of methane. A methane explosion occurred which may have been associated with coal dust. Twelve men were killed and four more were seriously injured.

A fire was burning in the top brushings and round the coal rib. Attempts were made to extinguish the fire but approach against the ventilation was difficult. One of the methane drainage holes caught fire, and this was followed by roof collapses.

On the 26th February, production resumed from No. 12 and 13 North walls and from development drivages, with the approval of the Chief Inspector.

The primary cause of the explosion was the inadequacy of the face ventilation. The district ventilation system was at its limit and had no margin to handle sudden drops in atmospheric pressure, gas feeders or temporary deviations from the normal air flow conditions.

The Elfstrom report was very critical of the Corporation, its mining engineers and supervisors regarding ventilation and safety standards. A number of unsafe practices were identified which included defeating safety controls designed to cut off power in the presence of methane. The Inspectors of Labour Canada and the executive of the Union were criticised for their failure to recognise fire and explosion hazards and it was noted that over 30% absenteeism of the labour force was not considered unusual.

The Report recommended that the training facilities and standards should be upgraded and concluded - "The only alternative to mine closure is to ensure that the Corporation meets the requirements of the Act and Regulations in all respects".

3.6 FIRE AT BOOSTER FAN, NO. 9 SOUTH, NO. 26 COLLIERY
12 OCTOBER 1982

Smoking materials found in the vicinity of the booster fan control station indicated that the fire had started from the use of this contraband material. A wooden doorframe was probably the first item to catch fire and be fanned by the high air velocity.

The mine was cleared of men. Six days production was lost.

A report was made by Labour Canada. Recommendations called for better training of booster fan attendants, and tighter control of contraband.

3.7 FIRE IN MAIN DEEPS NO. 26 COLLIERY, 5 APRIL 1984

At about 7 o'clock a.m. between shifts, smoke was smelled by men staying overtime to do some maintenance work. The manrider was able to bring out all the men except one, who is presumed to have taken a wrong road.

The fire was tracked down to the No. 7 drive in a series of 12 conveyors in tandem in the deeps. This unit is located at No. 5 South level. The conveyor attendant appears to have left his jobsite early (all 12 drives have an attendant).

Attempts were made to fight the fire with water, and later with nitrogen. Water pressure problems and rapidly escalating combustion forced a decision to seal off the Harbour Seam workings with fire stoppings. Ventilation was reduced to limit the fanning of the flames.

The five seals were completed by 5:30 am on April 7 (46 1/2 hours after raising the alarm).

Attempts were made to extinguish the fire by pumping liquid nitrogen into the burning area through a 12 inch diameter compressed air pipe which had been uncoupled near the fire. A total of 30 million cubic feet of the gas was brought by rail from Montreal and pumped 4 1/2 miles underground for a full week.

Production ceased after that night shift and 1145 men were laid off. Many of these were transferred to the new Phalen mine which started production from its first face in the Spring of 1987. A few men were retained to salvage some material from No. 26 Colliery.

The cause of the fire may it was discovered that the conveyor attendant had left his workplace early and arrived at the surface at 6:00 a.m. Conveyor problems (such as overheating at the drive) might have arisen during his absence.

TABLE 3-1
MAJOR INCIDENTS IN CBDC COLLIERIES
1973 - 1988

<u>DATE</u>	<u>LOCATION</u>	<u>INCIDENT</u>	<u>CAUSES</u>	<u>DAYS LOST PROD.</u>	<u>TOTAL ESTIMATED COST \$ MILLIONS</u>	<u>ACTION</u>
1973	No. 12 Mine	Fire. One Fatality	Power lost on hoist- braked-rope broke-coal cars ran away	60	27.5	Mine Abandonment. Patching Commission Inquiry
1975	No. 26 No. 11 South	Fire. Methane ignition from picks	Shearer/ Stone intrusion caused ignition	120	24.4	Wall Abandoned. Reports: Leblanc, Eaton Inquiry
1977	Lingan 4 East	Fire.	Shotfiring at back brushing ignited methane	10	0.9	No Inquiry
1979	No. 26	Explosion from picks. 12 Fatalities	Inadequacy of wall face ventilation	44	13.0	Elfstrom Inquiry. Part Production resumed after 1 day
1982	No. 26	Fire #9 South Booster Fan	Discarded cigar butt or match	6	2.2	Production resumed after 6 days. Labour Canada Investi- gation & Report
1984	No. 26 Main Deep	Fire in main deeps. One Fatality	Unknown	60	157.7	Mine Abandoned. Labour Canada Investi- gation and
<u>Sub Total</u>					<u>225.8</u>	
85-88	3 Mines CBDC	90 Minor Incidents	Various		0.6	Better info., analysis and cost alloc.
<u>Replacement Capital</u>					<u>289.0</u>	

Total including replacement and minor incidents

515.4

4.0 MINOR INCIDENTS

4.1 INTRODUCTION AND COMMENTS

Records of 90 incidents with serious fire potential, reported by CBDC, between April 1985 and March 1988, were obtained from Labour Canada. The 90 incidents have been grouped into 8 fire cause/risk categories. (See table 4-1 following). These incidents were all investigated by Labour Canada staff in conjunction with CBDC personnel. In this three year period the records are more detailed than those of earlier years and are considered to present a true picture of what is actually happening in the mines. Investigation records of many of the incidents were examined (Copies are not reproduced with this report). These records portray a sincere commitment to the cause of safety on the part of CBDC and Labour Canada.

The investigation records differ from most accident lists in that the name of an involved person is not included. This is done for two reasons: firstly, in many of the incidents, there was no injury, i.e. the incident described was a potentially dangerous situation which could have developed into a fire. Secondly, in this type of statistical document, it is considered unnecessary to disclose the name of an injured person.

The incident documentation was used to draw up a list of the incidents, analyse them, make some deductions and draw conclusions. The "List of Underground Incidents 1985 - 1988" is given in Table 4.2. Only items deemed to show a potential cause of fire have been noted. It is a credit to all concerned that the dangers of these incidents were recognized by the workmen and junior officials who reported them.

TABLE 4-1
SUMMARY OF FIRE CAUSE/RISK INCIDENTS BY CATEGORY

<u>Code</u>	<u>Category</u>	<u>Number</u>	<u>Percentage</u>
A	Conveyor idlers	33	37
B	Electrical cables	21	24
C	Electrical switchgear & Motors	12	13
D	Conveyor Drives	10	11
E	Miscellaneous	6	7
F	Sparking from rocks	3	3
G	Methane Accumulations	3	3
H	Machinery	1	1
Others		1	1
		--	---
		90	100
		--	---

The following comments are made regarding each category.

Conveyor Idlers.

Bottom idlers represent the largest number of incidents reported. Many were occurrences where smoke was generated by a combination of frictional heat and coal dust. Indications are that damaged bottom idlers due to bearing failure, and stone or wood preventing rotation, are two of the main causes of the reported occurrences - often discovered at weekends when the conveyors are stopped and the heat is not dissipated by the moving parts.

Electric Cables.

This is the next most frequent cause of incidents resulting from damage to the outer sheath and to cores, sometimes accompanied by short circuit flashes. This is an obvious danger if a high methane content or coal dust is present in the surrounding atmosphere.

Electric Motors and Conveyor Drives.

These incidents raise questions of design, selection, installation, maintenance and operation. Conveyor drives in particular, if neglected, can lead to large fires.

Sparking from Rocks

Machine picks cutting into incendive types of rocks, (usually of high silica content) is the most common fire risk. A shearer drum, with high pick speed, represents a greater danger than slower pick speeds.

The costs incurred by these many and varied incidents were noted in some of the reports. Costs estimated on the Incident Report Forms have been used to check our assessments. To estimate lost production time, which accompanies most incidents, an average production rate of 200 tonnes per hour per face has been assumed with coal at the face value at 50% of \$68 (\$6,800 per hour). A conservative estimate of the cost of each incident has been attempted and these add up to a sum of \$663,000 incurred over the three year period 1985-1988.

For the purposes of this review, it is pertinent to make the following comments:

- . The minor incidents (about thirty per year) while not causing extensive injury and damage, could have developed into major fires had the conditions been right.
- . The six major events which occurred in a 12 year period (average one every two years) all started as small incidents, similar to those described in Table 4.2.
- . There continues to be signs of disruptive and dangerous actions by a few men working underground, as evidenced by reports of cigarette butts being found; a bomb threat, and the irresponsible operation of fan and conveyor emergency stop, pull-cords.

A review of these minor incidents together with the characteristics of the six major ones clearly shows that each minor incident has the potential to become a human and financial disaster unless effective counter-measures are initiated and maintained.

TABLE 4-2

LIST OF UNDERGROUND INCIDENTS 1985-88

<u>Date</u>	<u>Mine</u>	<u>Place</u>	<u>Code</u>	<u>Incident</u>	<u>Est. Cost \$000s</u>
85-04-08	Prince	5 East	E	Fire in end of hollow shaft of shearer drum drive	20
85-04-09	Prince	6 East	C	Cable coupler to SF6 - flash-power off	8
85-04-30	Prince	5 E. Ret	B	Shearer cable flashed	9
85-06-17	Prince	3 Slope	B	DRCL cable box to cutting head flashed - bolts slack	10
85-06-19	Lingan	9 East	E	Thruster brake on haulage smoking - extinguisher	10
85-06-28	Lingan	3 Deep	A	Return idler bearing collapsed - hot	2
85-07-03	Lingan	8 East	D	Sparks from brakes - cooled - reset	3
85-07-9	Phalen	4 Slope	B	DOSCO cable flashed and tripped	5
85-07-11	Prince	4 Slope	D	Conv. belt stalled in drive -cut out belt	5
85-08-30	Lingan	4 Booster	D	Smoke down 3 deep from booster belt roller	10
85-10-02	Lingan	8 East	C	Smoke from haulage gate end box	5
85-10-16	Prince	5 West	B	Dosco cable coupler flash	5
85-11-02	Phalen	-	B	Mono pump cable coupler flash	5
85-11-01	Lingan	3 Slope	A	Idler bearing failed No. 3 conv.	2

<u>Date</u>	<u>Mine</u>	<u>Place</u>	<u>Code</u>	<u>Incident</u>	<u>Est. Cost \$000s</u>
85-11-02	Lingan	3 Slope	A	No. 5 Conv. idler bearing failed belt strings on shaft	3
85-11-04	Lingan	3 Slope	D	3 Conv.-overheated scoop coupling	15
85-11-04	Lingan	8 East	A	Smouldering under return idler	2
85-11-28	Lingan	3 Slope	A	8200 ft. bottom idler bearing hot	2
85-10-30	Lingan	7 East	A	Fines smoulder round bottom idler - bearing gone	2
85-12-03	Lingan	4 Deep	B	Flash on DRCL - wrong cable	5
85-12-03	Lingan	Surf	C	Switches damaged with flashover	15
85-12-15	Lingan	Surf	C	Switches damaged with flashover	15
85-12-14	Phalen	Surf	C	New switch ruptured	15
85-12-18	Lingan	3 Slope	A	4 Drive, hot fines round bottom idler	2
85-12-23	Lingan	9 East	C	Flash in Substation switch	10
86-01-09	Lingan	8 East	A	Hot roller 2nd loop take-up	2
86-01-16	Lingan	8 East	B	Ruptured armoured cable by shotfiring	10
86-02-05	Lingan	3 Conv.	A	Hot roller	2
86-02-06	Donkin	-	B	K69 cable coupler on TBM circuit ruptured	15
86-02-07	Prince	3 Slope	A	2 Drive tail pulley shifted - smouldering belt stringers	2

<u>Date</u>	<u>Mine</u>	<u>Place</u>	<u>Code</u>	<u>Incident</u>	<u>Est. Cost \$000s</u>
86-02-07	Prince	3 Slant	H	Smoke from failed brake thruster	10
86-02-07	Lingan	8 East	A	2 Take-up idler smoulder	4
86-02-14	Lingan	8 East	A	Idler near 5 drive smoulder	2
86-03-04	Lingan	4 Deep	A	5 Drive smoulder 4 idlers from tail end	2
86-03-05	Lingan	3 Deep	A	5 idlers below 8E flame	2
86-03-07	Lingan	2 Deep	F	Dosco hit hard stone - heavy sparking - flame on floor	5
86-03-07	Prince	3 Slope	B	Cable coupler failure SVAI -85-40	5
86-02-13	Lingan	9 East	A	2 Drive, Smoulder on snub pulley	5
86-03-07	Lingan	2 Dev.	F	DRCL struck stone intrusion	5
86-03-17	Lingan	8 East	A	Sparking top belt roller	2
86-03-20	Lingan	3 Slope	A	2 Booster, Smoulder on tail pulley	5
86-04-01	Prince	4 West	A	Smouldering duff due bad bearing bottom idler	4
86-04-19	Lingan	6 West	B	Elec. flash 1 man burned on arms	5
86-04-26	Lingan	3 Slope	A	Belt Rub on Structure - coal smoulder	2
86-04-19	Lingan	6 West	B	Flash and burns to electrician - cable	3
86-04-30	Lingan	6 West	F	Shearer struck stone - ignition	10

<u>Date</u>	<u>Mine</u>	<u>Place</u>	<u>Code</u>	<u>Incident</u>	<u>Est. Cost \$000s</u>
86-05-07	Lingan	8 East	D	2 Drive - conveyor stuck - belt heat up	5
86-05-10	Lingan	10 East	G	Crack in pavement 42' from face CH ₄ 40%	50
86-05-21	Lingan	8 East	A	4 Drive snub pulley - smoulder	4
86-05-29	Lingan	3 Slope	A	6 Drive - hot bearing in roller	2
86-05-29	Lingan	3 Slope	A	3 Drive - idler roller smoulder	2
86-06-19	Lingan	7 East	B	Cable coupler flash	3
86-06-23	Lingan	?	D	4 Booster belt broke - smoke - took belt off	10
86-06-26	Lingan	6 West	C	Flash bottom brushing gate end box	5
86-06-30	Lingan	3 Deep	D	4 Booster belt burned - turned over - flames	10
86-08-22	?	3 Slope	A	5 Drive - idler bearing tail - spark	2
86-08-29	Lingan	3 Slope	A	Idler shaft collapsed - heated - changed	2
86-09-11	Phalen	2 Angle	D	Slack conv. belt-smoke	5
86-09-19	Lingan	6 West	B	Cable flash	5
86-09-26	Lingan	9 East	A	3 Conv. broken bearing - hot	2
86-10-20	Lingan	11 East	B	Flash on DRCL	5
86-10-31	Lingan	10 East	C	Flash at SF6 Section switch in return airway	10

<u>Date</u>	<u>Mine</u>	<u>Place</u>	<u>Code</u>	<u>Incident</u>	<u>Est. Cost \$000s</u>
86-12-12	Prince	5 West	A	Hot bearing with flame conv. idler	3
87-01-06	Lingan	9 East	A	Fire low side 9 East conveyor	10
87-01-14	Prince	6 West	C	Flash in conveyor motor pothead	10
87-01-24	Lingan	3 Slope	A	Hot return idler	2
87-02-03	Lingan	6 West	B	Electrical Flash - assume cable	20
87-02-20	Lingan	10 East	G	2.4% methane at measuring sta. in return	5
87-04-03	Prince	-	C	Flash in switch of Dosco header	5
87-04-09	Lingan	10 East	B	Flash in Eimco cable	5
87-05-06	Lingan	9 East	C	Flash on Dosco at Intake brushing	5
87-05-22	Lingan	9 East	B	Cable cut by falling stone on face	20
87-05-26	Prince	7 East	A	Cable cut through by belt	20
87-06-15	Lingan	9 East	A	Hot bearing on idler - coal fire	2
87-05-19	Phalen	Silo	E	Fire in silo shute	5
87-08-13	Prince	9 East	A	Fire from hot bearing AFC return drive	30
87-08-17	Prince	2 Slope	E	Matches found in rake	-
87-09-09	Lingan	2 Slope	G	Methane ignition and coal dust	2
87-09-08	Prince	3 Slope	C	Flash gate end box for Dosco	5

<u>Date</u>	<u>Mine</u>	<u>Place</u>	<u>Code</u>	<u>Incident</u>	<u>Est. Cost \$000s</u>
87-10-26	Prince	4 Slope	D	4 Drive - heating on motor shaft?	20
87-11-03	Phalen	2 West	B	Earth fault on feeder cable	15
87-11-10	Lingan	7 West	B	Ran over electric cable	5
87-11-28	Lingan	3 Slope	A	3 conveyor - fire on return idler	2
87-12-12	Lingan			Anonymous bomb threat underground hoist	20
88-01-20	Lingan	7 West	B	Trailing cable flash	5
88-01-27	Prince	7 West	B	Trailing cable flash	5
88-03-05	Prince	3 Slope	E	Cap lamp cable heated and melted	-
88-03-08	Prince	3 Slope	E	Cigarette butt found in mine	-
88-03-15	Prince	5 Slope	D	Extending conv. drive turned on belt burned with smoke	10
88-04-19	Lingan	3 Slope	A	3 drive - flame 1st bottom idler inbye loop	5 -----
				Total all incidents	645

Average cost per incident \$7,167

5.0 SOCIO-ECONOMIC CONSIDERATIONS

5.1 THE RAND AND THE DONALD REPORTS

The Rand Report in 1960 recommended the gradual phasing out of coal mining replacing it with other industries. It pointed out the difficulties of mining coal 4 to 6 miles out under the sea and recommended reduction of output and a reduction of government subsidies which had been introduced in the 1920's.

In 1966 Dr. Donald reported on the Cape Breton Coal Problem. At that time coal from other areas of Nova Scotia could be landed in Sydney at a lower cost than the local product. Coal shipped to Ontario Hydro was subsidised to the tune of \$7.85 per ton to match the price of imported American coal. Average mine production costs were \$12 per ton. Even in Halifax the subsidy was \$9.15 per ton. Dr. Donald recommended that future regional planning should be based on the cessation of coal production after 1981.

The principal recommendations were:

- . Establishment of a Crown Corporation to oversee the reduction of coal production.
- . The Corporation would be capitalized with \$150 million over 15 years.
- . The Corporation would promote and establish new industries.
- . An enlightened retirement plan should be adopted.
- . Advice from the National Coal Board should be accepted.

These two reports provided the awareness that things were about to change in the Coal Industry. To compound the problem, the Sydney Steel Plant came under Provincial Control with a similar mandate to improve costs and match production to the markets.

5.2 MANAGEMENT LABOUR RELATIONSHIPS

The Patching Commission of Inquiry into the fire and explosion that resulted in the abandonment of No. 12 Colliery in 1973 provides insight into the nature of the corporation at that time. The Commission stated, "Patterns of work, and attitudes, plus the traditions and relationships between management and employees that has developed in the past are not appropriate to current circumstances and needs. The present (1974) management and employees have inherited these working patterns and traditions and now must try to develop more positive attitudes toward production and to safety of work... The Royal Commission Reports of 1947 and 1960 on the Canadian Coal Industry referred to the long history of strife and bitterness between the employees and the previous owners and management of the Cape Breton mines..."

"From observations in the mines and from the review of accident reports and statements at the hearings, the main task of senior management will be to develop a more positive attitude to safe and careful working practices on the part of the employees and to improve the effectiveness of the supervision, especially that of first line supervisors. Coupled with this is a necessary change in attitude between the workers, and supervisors who must be given sufficient authority to control the working practices in their jurisdictions"... and on the role of unions "more UMW members should be sent to UMW safety training courses and seminars provided by the International Union".

Subsequent Commissions of Inquiry into incidents in 1975, 1979, 1982 and 1984 reported many of the same findings, that Patching had referred to as housekeeping, oily rags, cigars, cigarette butts and matches, plus technical job and preventive maintenance

standards for reporting and monitoring gas, and sub-standard mine ventilation.

5.3 MEASUREMENT OF SOCIO-ECONOMIC COSTS

This task can be approached in many ways, such as the movement of people out of the area, increase in unemployment, bankruptcies, house repossession etc.

The difficulties are compounded by the similar patterns of other major industries in the area, notably the Sydney Steel Plant, the Heavy Water Plant at Glace Bay (Atomic Energy Canada Limited) and the Fish Plant in Glace Bay; the latter two closed down in 1984 with the combined loss of about 700 jobs.

However, some records have been found which indicate the economic costs of each incident. These are shown in Table 6-3 in Section 6.0 of this report.

The fires in the seventies did not have a major impact on the community because jobs were found elsewhere as follows:

1973	No.12	Closure. All men to Princess and Lingan
1975	No.26	No. 11 South Ignition - most of the men transferred to prepare the new face at No. 12 South
1977	Lingan	4 East. One face was down only 2 weeks.
1979	No. 26	12 South - production resumed after 5 weeks.
1982	No. 26	Booster Fan Fire - the mine was idle for only 6 days

1984 No. 26 Closure. 1145 men were laid off. This is the incident for which most cost data was available. It is recorded in Section 6.0 dealing with costs. By 1987 all these men were working at Phalen or had retired.

5.3.1 Population

Table 5-1 shows some interesting statistics over the period 1976-1981-1986. The major items are:

- . The population of the County of Cape Breton and the town of Glace Bay fell significantly in the ten years (by 3.6% and 6.4% respectively);
- . Young women left the area in greater numbers than the men;
- . A few people over 65 retired.
- . Unemployment approached 30% for the 15-24 age group in 1981, but fell to less than 10% in the over 25's;
- . The wage levels are lower than many areas in Canada (but so are living costs). However, there appear to be other inducements to seek work elsewhere.

A further set of figures, showing changes in taxpayer population, indicate that Cape Breton County experienced quite wide swings in migration patterns (Table 5-2). Over the 10 year period there was a net outflow of 7,410 people.

5.3.2 Employment

Statistics for the labour force in the whole of Cape Breton Island from 1975 to 1987 show a net increase of 6,000 jobs or about 11%. (See Table 5-3). In spite of this, unemployment for the whole of Cape Breton Island was generally in the high teens, with short term increases up to 24% during 1985 just after No.

26 and the other two plants in Glace Bay shut down. A recent statistic showed Cape Breton employment increased by 6,000 jobs from May 1984 to May 1988, an increase of 11% in four years.

Table 5-4 shows the Population estimates for Cape Breton Island by age groups 15 to 24 years and over 25 years. Increases occurred in the over 25 age group of both sexes. The number of 15 - 24 year olds declined.

A further table (Table 5-5) shows the employment levels by industry on C.B. Island. The increase occurs mainly in the service sector.

In 1985, after the closure of No. 26 Colliery and when the whole country suffered high unemployment rates averaging in the low teens, Cape Breton figures were considerably higher. Table 5-6 shows the very high numbers for Cape Breton youth who were unemployed (up to 47%).

5.4 SAFETY AND TRAINING PROGRAMMES

The many Commissions appointed to study the Cape Breton Coal Industry all concluded that changes were needed in many of the attitudes found in Cape Breton's Coal industry. It is recognized in most industries that one of the best ways to move away from the adversarial roles adopted by labour and management of the past is to formulate a safety policy which brings the two sides together. It is very difficult to oppose safety improvements, therefore such a programme can be the beginning of a cooperative effort to reach common goals.

It is impossible to say just how much the major incidents listed in this report prompted the safety drive but, in September 1985, the President of CBDC, Mr. Rance, introduced a Corporate Policy on Safety and Health. This Policy is based on the implementation of a Safety/Loss Control Audit System using the methodology of the International Loss Control Institute. The diagram in figure 5.1 traces the CBDC procedures following a reported injury and the follow-up steps to avoid a re-occurrence of the accident.

The University College of Cape Breton has been a major factor in raising the level of education and in broadening the range of mental tools available within the working community. The growing awareness of changes in markets, education and technology outside of Cape Breton was in the embryo stage at that time.

The opening of the Cape Breton Development Corporation's Adult Vocational Training Centre, in 1981-82, now provides training in much of the newer mining equipment, such as electrical, hydraulic and electronic systems used in modern mining and similar to that recently installed in Phalen. A visit was made to classes and to the fully operational part-face installation equipped with real machines and systems. In particular, the new control systems were designed to increase safety and replace many of the unskilled monotonous jobs such as fan attendants and conveyor drive operators. About 30% of the CBDC workforce now attend a course of some type each year.

The apprenticeship programme, started in 1974 and although suspended for a short period, it has proved invaluable for training skilled tradesmen and technicians drawn from the younger generation.

Proof of the effect of these training and management development programmes is the decreasing accident rate (in terms of lost time accidents per million man hours). Table 5-7 shows the improving trends, particularly at Prince Mine, a smaller more easily controlled mine.

These improvements are further illustrated by the charts, figure 5-2 and figure 5-3. A further example of the formalization of training for safety is the fire loss control programme. A copy of the training chart is attached as figure 5-4.

As part of the safety improvement scheme, audits are taken of the physical conditions at the facilities of the Corporation. A sample sheet is attached as table 5-8.

Table 5-1

SELECTED CHARACTERISTICS FOR CENSUS SUBDIVISIONS

Characteristics	1976	1981	1986	%Change 81-86	%Change 76-86
Population/Land Area	All figures in thousands				
Population - County of Cape Breton	128.2	127.0	123.6	-2.7	-3.6
- Glace Bay	21.8	21.8	20.4	-6.4	-6.4
By Sex and Age Glace Bay					
Male Total	10.8	10.5	9.9	-5.7	-8.3
Years of Age					
0-14	3.1	2.6	2.2	-15.4	-29.0
15-19	1.2	1.2	1.0	-16.6	-16.6
20-24	1.0	1.0	0.9	-10.0	-10.0
25-34	1.4	1.5	1.5	0.0	+7.0
35-44	1.1	1.2	1.2	0.0	+10.0
45-54	1.0	1.0	1.0	0.0	0.0
55-64	1.0	0.9	0.9	0.0	-10.0
65-74	0.4	0.5	0.7	+40.0	+75.0
75 plus	0.5	0.7	0.4	-42.9	-20.0
Female Total	11.0	10.9	10.6	-2.8	-3.6
0-14	2.9	2.5	2.2	-12.0	-24.0
15-19	1.2	1.1	0.9	-18.2	-25.0
20-24	0.9	0.9	0.9	0.0	0.0
25-34	1.4	1.5	1.5	0.0	+7.0
35-44	1.1	1.1	1.3	+18.2	+18.2
45-54	1.1	1.1	1.1	0.0	0.0
55-64	1.2	1.2	1.1	-8.0	-8.0
65-74	0.5	0.5	1.0	+100.0	+100.0
75 plus	0.7	1.0	0.7	-30.0	0.0
Average Number of Children	[Unitised basis]				
1 Family	1.5	1.6	1.5		

Table 5-1 (Continued)

SELECTED CHARACTERISTICS FOR CENSUS SUBDIVISIONS

Labour Force Activity 1981	Figures in Thousands	
	Glace Bay	County
Males in Labour Force		30.8
Employed	4.2	26.5
Unemployed	0.6	4.3
Participation Rate		
15-24 Years %	54.1	56.1
25 and over	64.9	71.2
Unemployment Rate (Average)	12.9	
15-24	28.7	29.9
25 and over	8.2	9.3
Average Income Males	12.2	13.0
Females	6.4	6.5
Family Income - Glace Bay	18.6	
- C.B. County		20.5
- C.B. Island	19.4	
- Province N.S.	21.9	

TABLE 5-2

IN AND OUT MIGRATION FLOW
CAPE BRETON COUNTIES 1977-86

YEAR	INVERNESS		RICHMOND		CAPE BRETON		VICTORIA	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT
1977	994	928	341	444	3059	4451	401	321
1978	872	1015	363	366	3237	3846	260	386
1979	1050	953	398	532	3303	3416	314	390
1980	943	1128	516	539	2978	3764	379	364
1981	899	1176	421	646	2777	3911	288	328
1982	741	913	361	446	2797	3735	312	277
1983	801	666	334	439	2828	2609	240	249
1984	659	585	375	333	2272	2264	175	167
1985	588	742	249	323	2017	2591	225	208
1986	441	937	208	461	1216	3307	125	206
TOTALS	7988	9043	3566	4529	26484	33894	2719	2896

NOTE: DATA IS BASED ON MOVEMENTS OF TAXFILERS (AGED 17+)

SOURCE: STATISTICS CANADA SMALL AREA DATA

TABLE 5-3

LABOUR MARKET INDICATORS FOR CAPE BRETON ISLAND
LABOUR FORCE SURVEY ANNUAL AVERAGES

YEAR	POP(1) -----000'S-----	LABOUR FORCE	EMPLOY	UNEMPLOY	PART'N RATE %	UNEMPLOY RATE %
1975	118	58	52	6	48.7	10.3
1976	114	56	49	7	48.9	12.5
1977	119	59	50	8	49.6	14.4
1978	123	63	53	10	50.9	15.2
1979	117	58	49	9	50.2	16.0
1980	115	59	51	8	51.1	14.1
1981	120	62	52	10	51.6	15.9
1982	124	62	50	12	49.7	18.7
1983	125	61	49	12	48.8	19.5
1984	127	67	54	13	53.2	19.7
1985	130	70	53	17	54.0	24.5
1986	131	72	56	16	55.1	22.7
1987	131	72	58	14	54.7	19.4

(1) Age 15+

SOURCE: STATISTICS CANADA LABOUR FORCE SURVEY

An additional statistic was recently collected:

Employment in Cape Breton	May 1984	54,000
Employment in Cape Breton	May 1988	60,000

Increase in Employment in Cape Breton in Four years (since the fire at No. 26 Colliery) 6,000 jobs

Expressed as a percentage, the increase is 11%

TABLE 5-4

POPULATION ESTIMATES FOR CAPE BRETON
 BASED ON LABOUR FORCE SURVEY DATA - AGED 15+

YEAR	-- TOTAL AGED 15+ --			----- MALE -----			----- FEMALE -----		
	TOTAL	15-24	25 +	TOTAL	15-24	25 +	TOTAL	15-24	25 +
1975	118.2	31.2	87.0	57.7	16.1	41.7	60.5	15.1	45.4
1976	114.1	28.1	86.1	55.5	13.6	41.9	58.7	14.5	44.2
1977	118.7	30.7	88.0	59.1	15.7	43.3	59.6	14.9	44.7
1978	122.9	32.5	90.4	61.0	16.9	44.1	61.9	15.6	46.3
1979	116.8	33.1	83.7	57.1	16.4	40.7	59.8	16.8	43.0
1980	115.5	30.1	85.3	55.6	14.8	40.8	59.9	15.3	44.5
1981	119.4	31.1	88.4	58.4	15.4	43.0	61.1	15.7	45.4
1982	123.7	30.1	93.6	61.3	15.0	46.3	62.4	15.2	47.2
1983	125.1	31.1	94.0	61.3	15.9	45.4	63.9	15.2	48.7
1984	128.1	30.4	97.7	63.1	15.7	47.4	65.0	14.7	50.4
1985	129.7	30.8	98.9	63.3	15.9	47.3	66.5	14.9	51.6
1986	130.6	28.0	102.6	63.8	14.8	49.0	66.9	13.2	53.7
1987	131.4	28.2	103.2	63.8	14.8	49.0	67.6	13.5	54.1

SOURCE: STATISTICS CANADA 3 MTH MOVING AVG DATA.

FIGURES ARE THOUSANDS

TABLE 5-5

EMPLOYMENT LEVELS BY INDUSTRY (000'S) 3 MTH MOVING AVG.
ANNUAL AVERAGES - CAPE BRETON

	TOTAL	AGRIC	OTH-PRIM	MAN	CONS	TRANS	TRADE	FIRE	SERV	PUB-ADMIN	UNCLASS
1975	51.6	0.0	4.7	8.2	4.3	6.8	8.8	0.0	13.9	3.1	0.0
1976	48.8	0.0	5.1	7.4	3.5	6.0	9.0	0.0	12.8	3.5	0.0
1977	50.4	0.0	5.4	7.5	4.1	6.0	8.8	0.0	13.6	3.6	0.0
1978	53.1	0.0	5.7	8.6	3.5	5.9	8.9	0.0	15.0	3.7	0.0
1979	49.1	0.0	5.3	8.7	3.8	5.1	8.7	0.0	13.4	0.0	0.0
1980	50.7	0.0	5.4	9.1	3.1	4.6	9.1	0.5	14.6	0.0	0.0
1981	52.2	0.0	5.3	8.6	2.6	4.7	10.0	0.5	15.8	3.2	0.0
1982	50.0	0.0	6.6	6.1	3.0	4.3	8.9	0.0	15.7	3.6	0.0
1983	49.3	0.0	8.3	4.9	3.6	4.0	9.0	0.0	15.3	0.0	0.0
1984	54.6	0.0	6.4	5.8	2.0	4.5	10.4	0.0	18.5	4.2	0.0
1985	53.0	0.0	4.3	6.6	2.7	4.8	9.9	0.0	19.0	3.3	0.0
1986	55.6	0.0	5.4	5.9	3.6	4.0	12.5	0.0	18.3	3.7	0.0
1987	58.0	0.0	5.7	7.0	3.6	4.1	12.0	0.0	20.2	3.4	0.0

NOTE: ZEROS INDICATE THAT THE DATA IS BELOW STATISTICS CANADA PUBLISHABLE LIMITS OF 2000.

AGRIC = AGRICULTURE, OTH-PRIM = OTHER PRIMARY, MAN = MANUFACTURING, CONS = CONSTRUCTION,
TRANS = TRANSPORTATION, FIRE = FINANCE, INSURANCE, REAL ESTATE, SERV = COMMUNITY, BUSINESS AND
PERSONAL SERVICE, PUB-ADMIN = PUBLIC ADMINISTRATION, UNCLASS = UNCLASSIFIED

SOURCE: STATISTICS CANADA

Table 5-6
 Youth Unemployment (%)
 Ages 15-24
 3 Month Moving Average

	1984		1985		1986		1987		1988 June	
	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO
Cape Breton	46.9	36.8	46.4	35.2	41.8	37.4	43.5	20.7	35.5	28.7
Nova Scotia	25.3	18.1	27.8	19.6	24.1	19.2	25.2	18.3	22.0	17.4
Quebec City				15.6	12.1					

Table 5-7

Lost Time Accidents Per Million Employee Hours

Underground In CBDC Mines

	<u>'83</u>	<u>'84</u>	<u>'85</u>	<u>'86</u>	<u>'87</u>	<u>'88 Ytd Jun. 11</u>
Mine:						
No. 26	313	279	-			
No. 26(1B)			120			
Lingan	479	391	371	259	212	210
Prince	417	322	278	147	176	133
Phalen	-	-	135 ^D	152 ^D	142 ^P	197
Total Corp. (Surface and Underground)	319	270	248	149	139	142

D - Development

P - Production

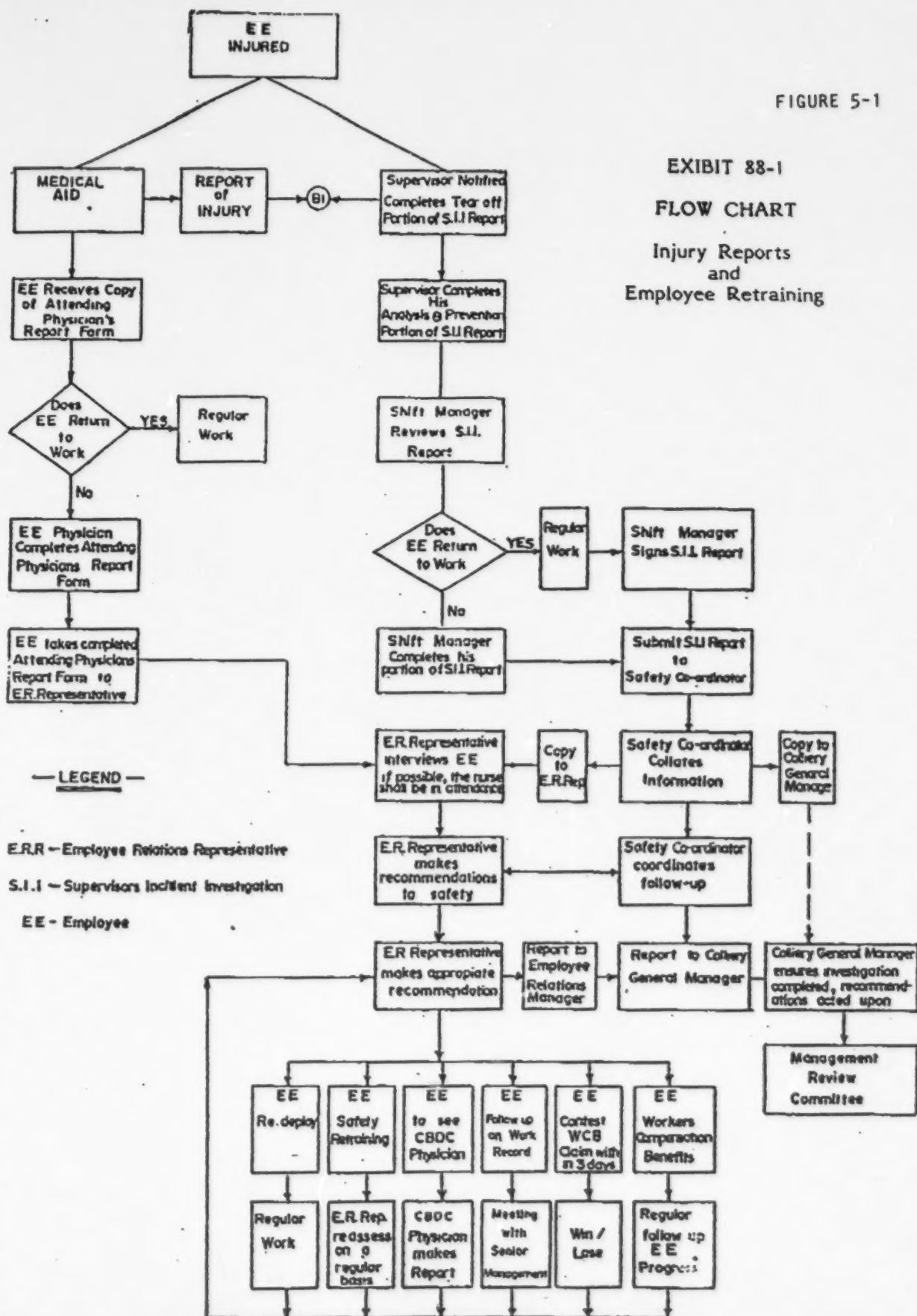
TABLE 5-8

PHYSICAL CONDITIONS ADDITS - SAMPLE

	BASELINE 1985	JUNE/1986	DECEMBER/1986	JUNE/1987		DECEMBER/1987	
				PH. CONDITIONS	FIRE PREV.	PH. CONDITIONS	FIRE PREV.
PRINCE	66.0	68.7	77.3	80.5	68.6	79.5	75.7
LINGAN	50.0	64.7	71.8	78.9	66	76.3	76.4
PHALEN	45.0	68.1	80.6	72.8	59.6	71.3	68.8
TRANSPORTATION CENTER	75.0	80.2	85	86.9	84.7	87.5	88.0
INTERNATIONAL PIER	76.0	85.2	93	90.4	86.9	89.3	84.8
LIFTING & BANKING	87.0	79.7	87	85.6		86.7	
DOMINION COAL YARD	95.0	95.2	92	91.3	92.5	90.6	95.0
QUALITY CONTROL	60.0	69.2	80	79.4	74.5	84.3	82.8
V.J. COAL PREP. PLANT	68.0	75.0	49.1	77.7	72.6	79.3	79.5
CENTRAL SHOPS	68.0	72.6	84.6	78.0	71.4	83.3	78.1
CENTRAL WAREHOUSE	66.6	74.1	85.7	87.1	89.5	84.9	86.0
C.B. CARBOPUELS	85.0	85.5	98	96.7	90	95.7	100
CORPORATION	59.5	74.4	76.7	79.0			

FIGURE 5-1

EXHIBIT 88-1
FLOW CHART
Injury Reports
and
Employee Retraining



CAPE BRETON DEVELOPMENT CORPORATION INJURY EXPERIENCE - SEVERITY

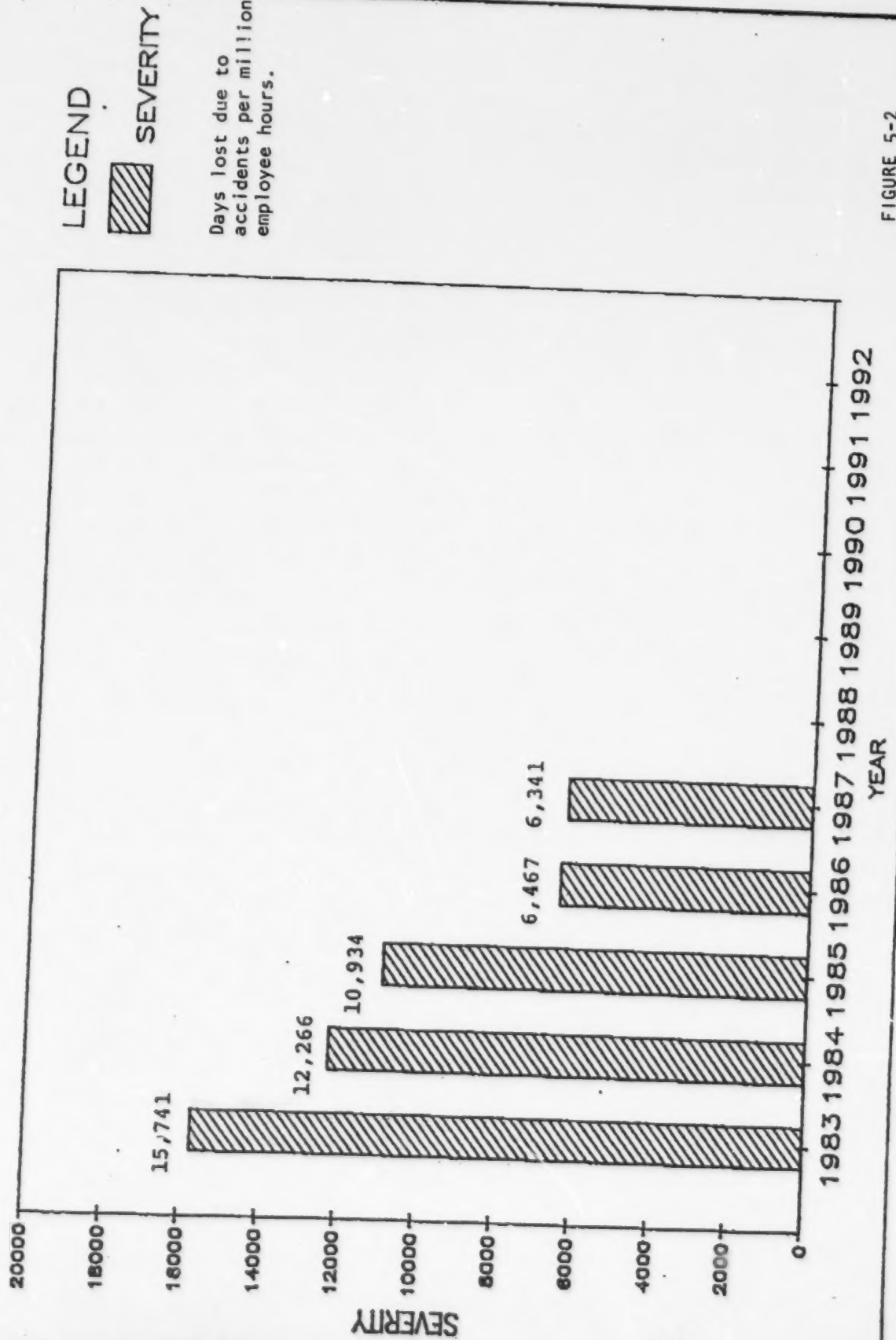


FIGURE 5-2

CAPE BRETON DEVELOPMENT CORPORATION MONTHLY ACCIDENT SUMMARY JANUARY 87/88

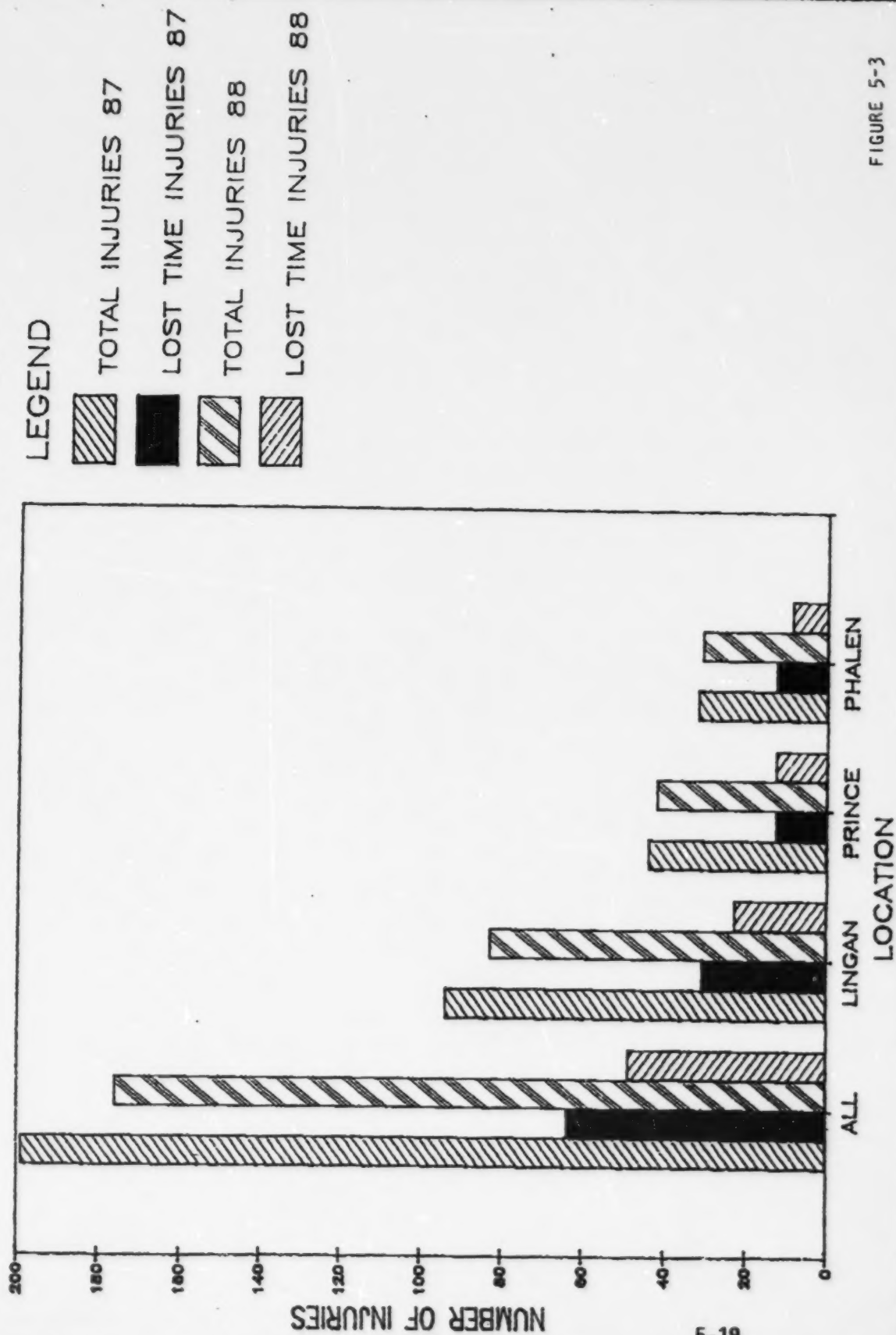


FIGURE 5-3

FIGURE 5-4

[illegible]

6.0 COSTS

6.1 INTRODUCTION

The problem of quantifying the full costs of mine fire incidents has concerned many people connected with the coal mining industry and unfortunately there have been numerous fire accidents over the years. Some mine owners have resisted the implementation of what, to them, appeared to be unnecessary expenditures to prevent occurrences which might never happen.

One classic example comes from England in 1835 when a Mr. John Buddle stated before a Select Committee "It might not be convenient to spend 20,000 pounds more to sink another shaft merely to avoid the chance of any accident which might eventually happen. In fact, I conceive if there were any legislative interference on that point, it would tend to extinguish a very large portion of our coal mines". This inquiry followed the disaster at Hartley Colliery when 204 men died because there was no second exit (in this case a second shaft). Eventually legislation required the provision of two means of egress where more than 9 men worked.

Certainly since that time, and perhaps earlier, many people have wrestled with the problem. Inexorably the costs of extra safety provisions are tied up with technology. Many of the advances in technology are based on improved production and hence lower cost of coal. An equally important consideration is the improved reliability of safety monitoring and controls systems which result in fewer dislocations of the production system. Any departure from the "normal" is likely to be more expensive.

The trend is towards increasing investments to provide highly capitalized operations, with the capacity to work close to 168 hours per week, and consequent reduction in high cost labour. However, labour represents over 50% of the operating cost at an average mine.

6.2 COST ASSUMPTIONS

In the case of the CBDC, some assumptions have been made regarding the value of reserves, value of coal produced for sale, fixed operating costs, costs of compensation, costs of incentives etc. These are listed below, with an explanation for their adoption where appropriate. The source of community costs is also explained.

- (1) Value of coal reserves: \$1 per tonne of saleable coal. The average coal thickness has been assumed as 2.0 metres.
- (2) Value of coal sold. The price of coal at the time of the incident has been taken from Table 2-1.
- (3) Costs of all categories at the time of the incident have been escalated according to Table 6-1.
- (4) Proportion of fixed operating cost - 50%. This is to cover permanent staff, power, taxes, fringe benefits and other overheads.
- (5) Average wage rates today of \$140 per day, plus \$60 in fringe benefits.
- (6) Rescue teams, if not already quantified by CBDC, at triple time.
- (7) Value of equipment. Major items have been presented at their written-down value. Minor equipment has been costed at today's replacement value.

- (8) Major mine replacements, such as \$184 million for Phalen have been put in a separate capital category. This is a major item and can be treated in different financial ways, such as capital for an independent project which ought to provide its own economic rate of return; or it can be considered a replacement cost for No. 26 as a direct consequence of the fire.
- (9) Inquiry costs have been estimated from the duration, number of organizations represented, recorded legal representation, days witnesses were off work, support by expert witnesses, etc.
- (10) Litigation costs - none have been recorded - but it is thought the 3 major incidents would have involved some costs.
- (11) Widow's benefits were vested and have been calculated at \$300,000 per fatality (1988 \$).
- (12) Workman's Compensation - actual payouts including penalties for fatalities.
- (13) Burns and Trauma. These are extra payments for transportation and subsistence to the Burn Unit at Halifax hospital.
- (14) Medical Plan is the extra cost due to paying benefits to the men not at work.
- (15) Supplementary benefits comprise vacation pay and any minor adjustments.
- (16) Bridge benefits are the cost to CBDC for providing 10 weeks work per year to enable persons to continue to draw U.I.C. payments. Although payments went on for three years for some men, calculations are based on two years for all men.
- (17) Loss of assessment is the loss to the municipality because the normal tax increases could not be applied in the difficult circumstances.

- (18) Lost wages represent the gross wages (net wages plus taxes) because of the incidents; they are calculated as follows:

For the No. 26 Closure

2 weeks waiting time for U.I.C. at \$500 per week for
1145 men plus 800 others

$$2 \times 500 \times 1945 = \$1.94 \text{ mill.}$$

plus 42 weeks per year at (\$500 - \$275) (average wage
minus U.I.C.) for an average of 1000 men for 2 years

$$= 42 \times \$225 \times 1000 \times 2 = \$18.14 \text{ mill.}$$

$$\text{total lost wages} = \$20.08 \text{ mill.}$$

For No. 12 Colliery

The calculation estimates 500 men

for 2 weeks at \$500 per week = \$ 500,000

plus 6 weeks at \$225 x 500 men = \$ 675,000

Total \$1.175 million

Similar calculations are used for the other incidents.

- (19) Provincial Contribution - See Table 6-2 - note that this includes the closure, at about the same time, of the other two plants in Glace Bay, and therefore cannot entirely be attributed to the fire. Total \$15.5 million.

- (20) U.I.C. calculated as 700 persons, 40 weeks per year, 2.5 years at \$275 per week.

A description of the extra payments made to the Town of Glace Bay under a Special Assistance Programme is summarized in Table 6-2. These payments were related, not only to the closure of No. 12 Colliery, but also to the closures of the Heavy Water plant and the fish plant.

Detailed cost estimates for each incident are itemized in Table 6-3 and a summary of the costs given in Table 6-4.

Other, less quantifiable, costs include statements from bankers etc. regarding personal loans. Those who were interviewed reported only a few customers asked to reschedule loan payments, and there were no mortgages foreclosed or commercial bankruptcies in Glace Bay. However, savings accounts dropped, particularly among young people. Home ownership exceeds 80% in Glace Bay. This probably plays a significant role in maintaining the stability of the local workforce.

6.3 COST EVALUATIONS

6.3.1 Review of Incident Costs

The cost estimates given in the previous tables draw attention to the following points:

- (a) The direct costs of the six fires to the Corporation was \$144 million.
- (b) The costs to the community was \$82 million, a very high figure.
- (c) If re-investment is added, the total cost is \$514.8 million.
- (d) In terms of numbers of the work-force affected, the closure of No. 26 Colliery had the greatest impact. Men laid-off numbered 1145 but, because the construction of Phalen Colliery was approved within

two months of this closure, all No. 26 men who did not retire or voluntarily leave, were placed in jobs by 1987. However, due to improvements in mining technology, the total number of jobs since that time has decreased by about 500.

- (e) The community cost of closing No. 26 was \$68 million distributed among 1145 men; this averages \$59,400/man.
- (f) The total costs, over a 15 year period, of the six major fire incidents are estimated to be -

. direct costs of the fires to CBDC	\$143.5 million
. capital asset replacement	\$289.0 million
total cost to CBDC	\$432.5 million
. Total community costs	\$ 82.3 million
. Total overall cost	\$514.8 million
	=====

6.3.2 Cost/Benefits - CBDC

The scale, complexity and fifteen-year time period covered by this fire/cost review, does not permit precise evaluation of cost/benefits to be made, particularly as they apply to the future. The total CBDC costs incurred by the six major fires are assessed at \$432.5 million over a period of 15 years; an average of \$28.8 million/year i.e. almost \$29 million per year. The question that arises is, to what level can fire costs be reduced? and how much can justifiably be spent on fire protection? Clearly these are questions for which a precise answer cannot be given, however, the following observations are made.

- (a) Over a three year period (from 85-04-08 to 87-04-19) there were 90 incidents from which fire did or could easily have resulted. These incidents incurred costs of \$215,000 per year.
- (b) The six major incidents, which cost CBDC approximately \$29 million/year over a 15 year period, started as "small" incidents.
- (c) CBDC already spends a substantial annual sum on underground fire prevention, including:
 - . purchase of new equipment
 - . maintenance of existing equipment
 - . engineering of specific fire prevention/control schemes
 - . firefighting training,
 - etc.

The principle benefits of improved fire prevention/control for CBDC are:

- . reduced cost of small incident fires.
- . reduced risk of fires developing into major incidents.

The total costs are estimated at:

- . small incident fires \$ 0.215 million/yr.
- . major fires \$28.800 million/yr.

Total average annual cost approx. \$29 million/yr.

It is certain that fire costs cannot be eliminated completely and it is unlikely, given the improvements made by CBDC in recent years, that major fires will continue to inflict the high costs of the last 15 yrs. Nevertheless, the possibility of a major fire cannot be dismissed.

To pursue the question of Cost/benefits further; suppose that by expenditures of half the potential cost of major fires and minor incidents, the frequency of minor incidents can be reduced by a third in each successive year. Because of the direct statistical linkage between minor and major incidents, it follows that the frequency of the major incidents will reduce accordingly. Table 6-5 shows 2 scenarios:

- 1) The Status Quo, in which the frequency of minor incidents continues at 30 per year, based on the 90 incidents in a 3-year period.
- 2) Effect of extra fire prevention expenditures as set out above.

Over the 5 year period depicted, the Status Quo projects a (potential) cost to CBDC of \$145 million. In the second scenario, extra expenditures of \$35 million on fire prevention result in a net (potential) cost saving to CBDC of \$40 million.

This is, as stated, a hypothesis in which:

- . the frequency of major fire incidents is "linked" to the number of minor incidents. Based on records studied, 1 in every 75 minor incidents can become a major fire (30 minors/year, 6 majors in 15 years);
- . extra expenditures on fire prevention result in a reduction of the number of minor incidents.

The hypothesis as set out is merely an example of a cost-benefit of extra fire prevention measures. The actual amount of money to be spent on such measures is a subjective judgement, as is the effect on reducing minor incidents.

However the approach leads to a method of evaluating expenditures against direct results in terms of less incidents, and can:

- . help guard against under or over provision of funds for fire prevention and control, and
- . offer some measure of the financial expectations which improved fire prevention measures should produce over a period of time.

6.3.3

Other Benefits

By preventing/minimizing underground fires benefits accrue to the community which are difficult, if not impossible, to calculate. Fewer fires reduce "lost-time" and the associated costs of compensation and lower earnings. It has been shown that relief from the effects of major fires in the last 15 yrs resulted, directly and indirectly, in Federal and Provincial costs amounting to \$82.3 million, - an average of \$5.5 million/yr. Therefore, while cost effective spending on fire prevention is in the hands of CBDC, benefits should be felt at local, Provincial and Federal levels.

The Canadian and Nova Scotian economic scenarios of 1984, when No. 26 Colliery was closed, are quite different from the economic conditions of today. No-one should assume that similar levels of Government financial assistance would be repeated if another major fire disaster was to occur.

The remaining mineable reserves of the Sydney Coalfield are submarine. There are three operating mines which access these reserves, Langan, Phalen, and Prince plus the Donkin-Morien Tunnels. Due to previous, on-shore mined-out areas, no other viable means of access to off-shore reserves are available.

If one of the three operating mines was to be lost (due to fire) there is no other developed mine left to absorb the labour force. Donkin Morien would take at least a year to bring into full production. After Donkin Morien, other viable mining options in the Sydney Coalfield will be very difficult to find.

A mine fire of disasterous proportions, that closes down another coal mine in Cape Breton, would seriously threaten the continued survival of coal mining in the Sydney Coalfield as a major industry.

TABLE 6-1

INFLATION RATES

1973	3.02
1974	2.72
1975	2.45
1976	2.29
1977	2.12
1979	1.78
1980	1.62
1981	1.43
1982	1.30
1983	1.28
1984	1.18
1985	1.13
1986	1.08
1987	1.04
1988	1.00

Source StatsCan - (with 87-88 estimated at 1.04)

TABLE 6-2
TOWN OF GLACE BAY
SPECIAL ASSISTANCE PROGRAM: 1984 - 1988

\$ Millions

	SOCIAL ASS'T COST ¹	PROV. ASS'T SPECIAL ²	GENERAL MINING BUILDING ³	GRANTS CBDC	IN LIEU AECL	OF TAXES ⁴ FISH PLANT	MILAP ⁵
84	1.05	0.90	0.04	1.38	0.36	0.02	
85	1.36	0.60	0.10	1.20	0.36	0.04	2.23
86	1.62	1.20	0.10	0.80	0.36	0.04	2.23
87	1.92	1.20	0.12	0.47	0.16	0.04	2.23
88	1.80	1.60	0.12	0.48	0.08	0.04	2.23
Total	7.75	5.50	0.48	4.33	1.32	0.18	8.92

1. Grants to replace industrial taxes to pay for ageing population, senior citizens nursing homes, training courses, etc.
2. Grants to cover shortfall in Town income by not being able to increase the mill rate.
3. Taxes payable by CBDC above the rent paid for the General mine Building in Glace Bay - The main offices of CBDC.
4. Grants in place of industrial taxes formerly paid by the three industries.
5. Municipal Industrial Labour Assistance Programme (MILAP)
Criteria - Age 54 at time of fire with 1,000 hours work each year for previous 10 years.
- 147 men qualify, plus 18 on retirement.
- payment now \$292 per week, indexed.

TABLE 6-3

COST ESTIMATES - SIX MAJOR INCIDENTS

Millions of 1988 Dollars						
	Close 12 1973	11 South 1975	Lingan 1977	12 South 1979	Booster Fan 1982	Close 26 Apr. 1984
CBDC - COSTS						
Rescue Costs	2.2	0.7	0.05	0.1	0.1	22.4
Equipment Loss	6.0	3.7	0.25	1.0	0.5	28.3
Development Loss	6.0	5.2	-	-	-	-
Reserve Loss	1.4	0.7	-	-	-	4.1
Production Dislocation	2.0	9.4	0.6	2.2	0.7	7.1
New Equipment	-	-	-	0.3	-	10.0
Sub-Total Mining	17.7	19.6	0.9	3.6	1.3	71.9
Inquiry	0.2	0.2	-	0.8	0.2	0.3
Litigation	-	-	-	-	-	-
Compensation	0.3	-	-	3.0	-	0.3
Widows	0.2	-	-	4.0	-	0.2
WCB	0.1	0.1	-	0.4	-	0.2
Burns Victims	0.2	-	-	0.3	-	1.5
Medical Plan	0.1	0.3	-	-	-	0.5
Supplementary	-	-	-	-	-	15.0
Bridge Benefits	-	-	-	-	-	15.0
Total CBDC Costs	18.8	20.2	0.9	12.1	1.5	89.9
						143.5

TABLE 6-3 (Cont'd)

COST ESTIMATES - SIX MAJOR INCIDENTS

	Millions of 1988 Dollars				
	Close 12 1973	11 South 1975	Lingan 1977	12 South 1979	Booster Fan 1982
					Close 26 Apr. 1984
					Total
Community Costs					
Lost Wages	1.2	3.6	-	-	20.1
Loss of Assessment	2.0	-	-	-	25.5
MILAP					4.0
Welfare	0.8	-	-	0.6	8.9
Prov. Contribution	-				1.8
UIC	4.0	0.3			15.5
Bankruptcies	-	-			19.2
Inquiry Cost	0.7	0.3	-	-	0.1
				0.9	0.2
Total Community Cost	8.7	4.2	-	0.9	67.8
Total All Costs	27.5	24.4	0.9	13.0	157.7
Capital Account	92.0	13.0	-	-	184.0
TOTAL COST	119.5	37.4	0.9	13.0	341.7
				2.2	514.8

TABLE 6-4

SUMMARY OF COST STATEMENTS OF INCIDENTS (\$MILLIONS 1988)

	Close 12 1973	11 South No. 26 June 1975	Ignition Lingan 4E June 1977	Explosion 12 S No. 26 Feb. 1979	Fire Booster Fan 82	Close No. 26 April 84	TOTALS
CBDC Costs	18.8	20.2	0.9	12.1	1.5	89.9	143.5
Community	8.7	4.2	-	0.9	0.7	67.8	82.3
Costs							
Sub-Total	27.5	24.4	0.9	13.0	2.2	157.7	225.8
Capital Costs	92.0	13.0	-	-	-	184.0	289.0
Total Costs	119.5	37.4	0.9	13.0	2.2	341.7	514.8

THEORETICAL COST/BENEFIT OF FIRE PREVENTION

Table 6-5

(1) STATUS QUO :-

	Year					
	1	2	3	4	5	Total
No. of Minor Incidents	---	---	---	---	---	---
	30	30	30	30	30	150
Cost of Minor Incidents \$M	0.22	0.22	0.22	0.22	0.22	1.08
Potential Cost of Major Incidents \$M	28.83	28.83	28.83	28.83	28.83	144.16
Total Cost of Incidents \$M (Total Cost to CBDC)	29.05	29.05	29.05	29.05	29.05	145.24

(2) EFFECT OF EXTRA FIRE PREVENTION EXPENDITURES :-

	1	2	3	4	5	Total
No. of Minor Incidents	---	---	---	---	---	---
	30	20	13	9	6	72
Cost of Minor Incidents \$M	0.22	0.14	0.10	0.06	0.04	0.52
Potential Cost of Major Incidents \$M	28.83	19.22	12.81	8.54	5.70	69.41
Total Cost of Incidents \$M	29.05	19.36	12.91	8.61	5.74	69.93
Fire Prevention Expenditures \$M	14.52	9.68	6.45	4.30	2.87	34.96
Total Cost to CBDC \$M	43.57	29.05	19.36	12.91	8.61	104.89
NET COST SAVING TO CBDC \$M						40.34

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

It must be remembered that, in spite of improved technology, mine fires and explosions continue to occur in the coal mines of the world - even where advanced mining technologies are employed. Constant vigilance and commitment is required at all levels to:

- . remove potential fire hazards
- . detect fire at its inception and,
- . be prepared to combat underground fire intelligently.

The CBDC has devoted considerable effort and money, since the closure of No. 26 Colliery, to the detection and combat of fire and ways to overcome the hazards of underground fire. Training programmes have been introduced but improving and maintaining management, supervisor and worker preparedness is a never-ending task.

7.2 RECOMMENDATIONS

- (a) Continue and improve the collection of cost data related to fires, including the manner the fire was dealt with and reported.
- (b) Loss Control personnel should attempt to develop ways to evaluate the cost/benefit of fire prevention expenditures, possibly on the lines discussed in this report.

- (c) Details of fire incidents, their detection, treatment and costs incurred, should be posted on mine noticeboards. Persons taking appropriate and effective preventative action should receive recognition by management.

Stage 2 of this project provides for mine visits to examine the CBDC underground operations at the Lingan, Phalen and Prince mines. Fire prevention problems will be evaluated together with CBDC's implementation of remote fire detection methods, training, evacuation and fire fighting capability. The special problems of fire in the extensive, undersea mines of the Sydney coal field will be examined.

APPENDIX 1
CALCULATIONS OF MINING COSTS

APPENDIX 1

A NO. 12 MINE - CLOSURE 1973

<u>CBDC COSTS</u>	Source	Cost at Time \$	\$000s Cost Today
1. .Rescue 6 weeks rescue*			1392
.6 wks Dept. of Mines			
Drill Rig with crew	est.	163,127	493
.6 wks injection by			
Cementation Co.	est.		50
.6 wks Colliery staff			
& men			
sealing 8 openings,			
monitor & seal after-			
ward - say 30 men			
40 days at \$200			240
* Calculation 4 crews of 5 per			
shift 3 shifts/day 40 days.			
Wages \$140 x triple time +			
\$60 burden = \$480/day per man			
Total \$480 x 4 x 5 x 3 x 40			
= \$1,152,000			
Expenses at \$100/man/day			
60 men 40 days = \$240,000			
Total \$1,392,000			
		Sub Total	2175
2. Loss of Equipment	CBDC	\$2 mill	6,032
from CBDC	MacLean		
3. Loss of Development			
4 x 200 m main deep	from		6,000
2 x 200 m entry and face	plans		
1200 m @ \$5,000/m			
cost today)	rate CBDC		
4. Reserve loss at \$1 per			
tonne nominal amount)			
measured from plan -			
barriers against old			
workings, plus coal left			
in active panels	est.		1,417

	Source	Cost at Time \$	\$000s Cost Today
5. Dislocation of production time to dev. new faces for displaced men Assume 3 months dislocation with 50% fixed costs at revenue price today of \$68 at rate of 1,000 tonnes/day 60 days	est		2,040
SUB TOTAL	Operating Account		17,664
6. Replace equipment (capital above written down value of lost equipment) est 2 long- walls of the type at that time, \$12 mill. new rails, used hoists, conveyors, electrics, drivage (total 20 mill.) use a figure of half that of Phalen today (\$184 million)			92,000
SUB TOTAL	Capital Account		92,000
INCIDENT TOTAL			109,664

B FIRE NO. 26 11 SOUTH 1975

	Source	Cost at Time \$	\$000s Cost Today
1. Rescue	CBDC	296,663	727
2. Loss of Equipment on face (written down)	CBDC	1,500,000	3,675
3. Loss of Development 50% main deeps = 300 m plus entry and face Dev. 12S = 730 m. Total 1030 m at \$5,000/m			5,150
4. Reserve loss at \$1 per tonne 1500 m x 170 m x 2.0 at s.g. 1.4 = 714,000t at \$1.00			714
5. Dislocation of production 5 weeks no production all mine. 26 weeks at 1,700 tpd instead of 3,200 - i.e. loss of 1500tpd. Revenue loss per ton \$68 x 0.5 (50% fixed costs)	CBDC		2,720 6,630
SUB TOTAL	Operating Account		----- 19,616
6. Replace equipment on wall at that time (capacity etc.) gate conveyor & electrics			13,000
SUB TOTAL, CAPITAL ACCOUNT			----- 13,000
INCIDENT TOTAL			----- 32,616 -----

C LINGAN IGNITION JUNE 1977

	Source	Cost at Time \$	\$000s Cost Today
Ignition at 4 East Tail Gate hanging flame in brushing lip.			
1. Rescue - firefighting	CBDC	24,558	52
2. Loss of Equipment (major)			nil
3. Loss of Development			nil
4. Reserves Loss			nil
5. Output loss 10 days - est 1800 t x \$68 x 0.5 (to cover fixed costs)			612
6. Replace equipment - assume cable to tail drive was severly damaged, etc. 250 m @ \$1000/m			250
INCIDENT TOTAL			---
			914

D 26 COLLIERY - EXPLOSION 12 SOUTH 1979

	Source	Cost at Time \$	\$000s Cost Today
12 South 24 Feb. 1979 12 men killed (Elfstrom Report)			
1. Rescue Costs Estimate	CBDC	Nil	100
2. Equipment Costs Replace parts of shearer signals, methane detector chock parts est			1,000
3. Loss of Development		nil	
4. Reserves Loss		nil	
5. Production Loss 2 days no production at mine 40 days no production at 12 South only Total 44 face days at 1500 tpd value \$68.00 - use 50% for fixed costs			2,244
6. Replace Equipment		nil	
7. Investigation 3 experts U.K. 2 weeks on site 2 weeks report, plus expenses @ \$1500/day inclusive. 90 mandays			135
8. Ventilation improvements before restarting		est	150
TOTAL			----- 3,629 -----

Elfstrom committee of Enquiry - Est. Cost	
9 lawyers representing 9 organizations	
at \$2,000 per day	486
27 days of hearings	
115 witnesses 1 days wage @ \$200 aver.	23
Commission visit to European mines - est. 2 weeks	
10 people @ \$2,000/day	180
Hiring of hall	20
Misc. expenses	100

TOTAL	809

E 1982 FIRE AT BOOSTER FAN NO. 26 COLLIERY 1982

	Source	Cost at Time \$	\$000s Cost Today
Refurbish Booster station and fans	CBDC	400,000	520
Lost Production - 6 days 6 x 3,500 tpd @ \$68.00 x .5			714
Firefighting	est		100
Investigation	est		200
INCIDENT TOTAL			----- 1,552 -----

APPENDIX 2 -

F. No. 26 COLLIERY FIRE IN MAIN DEEPS APRIL 1984

	SOURCE	COST AT TIME \$	\$000S COST TODAY
1. Rescue	CBDC	190	224
2. Use of Nitrogen Freight	NOWSCO est	740 70	913
3. Direct Costs	CBDC	18,000	21,240
4. Loss of Assets (write-off)	CBDC	24,000	28,320
5. Loss of Development (new ancilliary equipment) Assume Phalen extra expenses			10,000
6. Loss of Reserves One more panel, i.e. 12 & 13 South, 13 North 2 x 3,000 x 243 x 2 x 1.4 x \$1.00			4,082
7. Dislocation of production 60 days, 3500 tpd at \$67.87 x .5			7,140
	Total		----- 71,919 -----

TABLE 6-3

COST ESTIMATES - SIX MAJOR INCIDENTS

Millions of 1988 Dollars						
	Close 12 1973	11 South 1975	Lingan 1977	12 South 1979	Booster Fan 1982	Close 26 Apr. 1984

CBDC - COSTS						
- Rescue Costs	2.2	0.7	0.05	0.1	0.1	22.4
- Equipment Loss	6.0	3.7	0.25	1.0	0.5	28.3
- Development Loss	6.0	5.2	-	-	-	-
- Reserve Loss	1.4	0.7	-	-	-	4.1
- Production Dislocation	2.0	9.4	0.6	2.2	0.7	7.1
- New Equipment	-	-	-	0.3	-	10.0
						10.3

Sub-Total Mining	17.7	19.6	0.9	3.6	1.3	71.9
						115.1
Inquiry	0.2	0.2	-	0.8	0.2	0.3
Litigation	-	-	-	-	-	-
						1.7
Compensation						
- Widows	0.3	-	-	3.0	-	0.3
- WCB	0.2	-	-	4.0	-	0.2
- Burns Victims	0.1	0.1	-	0.4	-	0.2
- Medical Plan	0.2	-	-	0.3	-	1.5
- Supplementary	0.1	0.3	-	-	-	0.5
- Bridge Benefits	-	-	-	-	-	15.0
						15.0

Total CBDC Costs	18.8	20.2	0.9	12.1	1.5	89.9
						143.5
Community Costs						
Lost Wages	1.2	3.6	-	-	0.6	20.1
Loss of Assessment	2.0	-	-	-	-	2.0
MILAP			-			8.9
Welfare	0.8					1.8
Prov. Contribution	-					15.5
UIC	4.0	0.3				19.2
Bankruptcies	-	-	-	-	-	0.1
Inquiry Cost	0.7	0.3	-	0.9	0.1	0.2
						2.2

Total Community Cost	8.7	4.2	-	0.9	0.7	67.8
						82.3
Total All Costs	27.5	24.4	0.9	13.0	2.2	157.7
						225.8
Capital Account	92.0	13.0	-	-	-	184.0
						289.0

TOTAL COST	119.5	37.4	0.9	13.0	2.2	341.7
						514.8

TABLE 6-4

SUMMARY OF COST STATEMENTS OF INCIDENTS (\$MILLIONS 1988)

	Close 12 1973	11 South No. 26 June 1975	Ignition Lingan 4E June 1977	Explosion 12 S No. 26 Feb. 1979	Fire Booster Fan 82	Close No. 26 April 84	TOTALS
CBDC Costs	18.8	20.2	0.9	12.1	1.5	89.9	143.5
Community	8.7	4.2	-	0.9	0.7	67.8	82.3
Costs							
Sub-Total	27.5	24.4	0.9	13.0	2.2	157.7	225.8
Capital Costs	92.0	13.0	-	-	-	184.0	289.0
Total Costs	119.5	37.4	0.9	13.0	2.2	341.7	514.8

Volume

2

INCIDENCE AND POSSIBLE CAUSES OF
FIRES WITHIN COAL MINES OF
THE NOVA SCOTIA COAL FIELDS
AND ON MEASURES THAT CAN BE TAKEN TO
PREVENT SUCH FIRES

STAGE 2

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1.0 INTRODUCTION1.1 CONTEXT AND OBJECTIVES

The report on Stage 1 of the project discussed experience with fires in mines of the Sydney Coalfields during the years 1973 to 1988. The costs of these fires were estimated directly, in terms of lost production and equipment, and socially, in terms of deaths, lay-offs, local taxes and social costs at local, Provincial and Federal levels.

Although these costs could not be determined accurately, the estimates showed that they were so high that programs to reduce the incidence of mine fires, and the damage caused by them, had the potential to save very large sums of money. The report concluded that some increase in expenditures on fire prevention and control could be justified but the actual cost benefits realized should be monitored.

In this Stage 2 Report of the project a review is presented of coal mine fires, their causes, prevention and detection, and means of combatting them. The particular conditions and problems of the Sydney Coalfield mines are examined, together with the Fire Protection Programs currently in place. Recommendations are made to reduce fire incidence and reduce risk and losses. Specific actions are recommended.

The report on Stage 3 of the project addresses selected items from the recommendations and provides capital and operating cost estimates to implement them.

1.2 STATEMENT OF WORK

The Stage 2 Statement of Work, taken from the original Terms of Reference, is as follows.

The Stage 2 review must include considerations of:

- a) the types of fires that occur within coal mines;
- b) the actual, probable and possible cause of mine fires;
- c) the prevention of mine fires;
- d) the monitoring and detection of mine fires;
- e) the control of and the fighting of mine fires to extinction;
- f) the means of attaining the rapid evacuation of personnel from within the mine in the event of a mine fire; and
- g) the impact of mine ventilation on the progress of fires.

The review must report on the organization, management and maintenance of fire fighting systems and monitoring methods adopted for the prevention of fires and the methods of monitoring and fire fighting within operating mines of the Sydney Coalfield.

It must also, as appropriate, identify any areas where it is considered that either change to existing practices or some further research is necessary and give estimates of the cost benefits of such actions.

1.3 THE WORK PROGRAM

Items (a) to (g) of the "Statement of Work" are addressed in general terms with references to previous technical papers. Attention is drawn to their relevance to the Sydney Mines where appropriate.

Underground visits were made by D.M. Parkes, P.Eng. and A. Strickland, P.Eng. to the Sydney Coalfield mines operated by the Cape Breton Development Corporation (CBDC). The program included two days at the Lingan Mine, two days at Phalen and one day at the Prince Mine.

Discussions were held with management and technical staff of CBDC both at the mines and at the central engineering and safety departments.

1.4 ACKNOWLEDGEMENTS

Special thanks are due to CBDC staff of the following departments:

- Vice President Operations
- Director Mine Engineering
- All three mine General Managers
- All three mine Colliery Managers
- Manager Loss Control Department
- Mine safety co-ordinators
- Mine fire prevention supervisors
- Mine rescue supervisors
- Corporate safety and training managers
- Corporate fire prevention supervisor
- Corporate ventilation engineer
- Corporate mine planning groups
- Corporate geological staff

Regular communication with Canmet in Cape Breton has assisted the consultants in preparing this report. In particular comments provided from members of the committee in Canmet's letter of December 6th, which refers to the first draft of the Stage 2 report, have been valuable in revising that draft.

2.0 TYPES OF MINE FIRES

2.1 INTRODUCTION

Mine fires are usually conveniently grouped into types or categories with defined characteristics. The choice and definition of the groups are determined by the particular aspects being discussed, consequently a fire may fall into more than one category. For example, a fire on a belt conveyor may be classified by its location (conveyors) or by its cause (friction).

Commonly used classifications refer to:

- . Characteristics of the fire - i.e. oxygen rich or fuel rich.
- . Severity of fires.
- . Burning material and suitability of extinguishants.
- . Causes of fire.

It is appropriate to discuss each classification in turn.

2.2 OXYGEN RICH AND FUEL RICH FIRES

A fire is oxygen rich when the oxygen supply is more than sufficient to enable combustible material to be completely burned. The advance of a fire front in an oxygen rich fire is directly proportional to the velocity of the ventilation. A reduction in ventilation can change an oxygen rich fire to a fuel rich fire.

A fire is fuel rich when there is insufficient oxygen to completely burn the fuel available. In this condition the speed of fire is unaffected by ventilation speed and the atmosphere may become charged with hot, incompletely burned vapours. The introduction of air (oxygen) into this atmosphere can produce sudden and violent burning of these vapours resulting in an explosion or "flash-over".

The behaviour of oxygen rich and fuel rich fires was examined in the U.K. in the late 1960's. ("The Possibility of the Occurrence of Fuel Rich Mine Fires" - A.F. Roberts, J.R. Blackwell; The Mining Engineer, September 1969).

Roberts and Blackwell experimentally developed a formula for a timber fuelled mine fire:

$$R = \frac{5 \times \text{Rate of Combustion of Wood}}{\text{Rate of Air Supply to fire}}$$

When $R < 1$, the fire is oxygen rich and when $R > 1$, the fire is fuel rich. Fuel rich fire conditions at Ogilvie Colliery - Wales, have been examined (Robinson Evans and Morgan Adams; The Mining Engineer, June 1972). An oil fire explosion at Mars No. 2 Mine, W.Va. 1965 was another example of a fuel rich fire.

2.3 SEVERITY OF FIRE

Fire types may be categorized in terms of severity. There are a number of ways in which this may be done, some examples being given in Table 2.1. Severity may be measured in terms of:

TABLE 2.1
SEVERITY OF FIRES

(Suggested Indicators)

TYPE OF FIRE	SAFETY LOST-TIME INJURIES	PRODUCTION (tonnes)	ECONOMIC LOSSES EQUIPMENT (\$ value)	LAY-OFFS (Man-Shifts)	OPERATIONAL EFFECT
MINOR	Less than 2	0 to 1,000t	0 to \$50K	None	Fire Localized No shut-down of operations
SERIOUS	2 - 5	1,000t to 10,000t	\$50K to \$1.5 mill	0 to 500	Section of mine temporarily shut down
MAJOR	5 - 10	10,000t to 750,000t	\$1.5 mill to \$10 mill	500 to 15,000	Section of mine permanently shut down (sealed off) - or - Whole mine temporarily shut down
DISASTEROUS	More than 10	Total Production of Mine	Over \$10 mill up to total value of lost assets less Insurance	+15,000 up to total labour force	Whole mine Permanently shut down (sealed off and abandoned)

- . Safety
 - Fatalities
 - Injuries
 - lost-time
 - no lost-time
- . Economic Losses
 - Production loss
 - Equipment loss
 - Lay-offs
- . Operational Effect
 - Permanent
 - Temporary
 - Partial

There are no well established standards but the kind of indicators that might be employed are given in Table 2.1.

In the UK an indication of frequency and severity has been used which is reproduced as Table 2-2 and shows by year:

- . open visible outbreaks of fire;
- . occurrences in which it was necessary to withdraw men from the mine due to smoke or signs of heating; and
- . the total of both types of occurrences; See Table 2.2.

It will be noted that foreign experience and statistics on fires referred to in these reports predominantly relates to mines in the United Kingdom. The use of foreign statistics and results in this assignment is essential to broaden the base of information utilized in arriving at conclusions and in making comparisons since there are only three CBDC underground mines. There are no others in Canada for which valid comparisons can be made.

TABLE 2.2

FIRE INCIDENTS IN U.K. COAL MINES 1976 - 1986
(OUTBREAKS OF FIRE - WITHDRAWALS OF WORKERS)

YEAR	(a) OUTBREAKS OF FIRE	(b) WITHDRAWALS OF MEN (DUE TO SMOKE, ETC.)	TOTAL (a) + (b)
1976	50	19	69
1977	57	16	73
1978	63	13	76
1979	55	13	68
1980	57	15	72
1981	49	23	72
1982	61	16	77
1983	50	16	66
*1984/85	38	8	46
1985/86	56	21	77

*NOTE: Year 1984 is omitted from cause classification. Details not available - national miners strike.

REF: H.M. Chief Inspector of Mines & Quarries Annual Reports.

The U.K. and Australian coal mines are particularly useful as sources of information since the experience is well documented, and mining conditions are similar.

2.4 BURNING MATERIAL AND SUITABILITY OF EXTINGUISHANTS

The International Standard Classification of Fires is reproduced in Table 2.3. Each type of fire (Types A to D) briefly describes the burning material and the type of extinguishant to be used. These same letter designations are used on fire extinguishers to indicate their suitability.

In the special case of fires involving electrical equipment, the power supply should be switched off as soon as possible. Extinguishers suitable for use on electrical equipment use a non-conductive extinguishant not harmful to electrical components. These extinguishers are sometimes designated for Type 'E' fires.

2.5 CAUSES OF FIRE

Causes of fire are commonly grouped statistically according to the areas of activity in which preventative or remedial measures can be taken, for example in mining, electrical and mechanical activities. These are then often subdivided into more specific areas to show where the frequency of fires is high enough to demand special attention. An example of this is given in Table 2.4 "Fires in UK Coal Mines 1976 - 1986, Causes of Fire - Categories".

A similar summary of Fire Cause/Risk incidents in the CBDC mines (Nova Scotia), taken from Stage 1 of this report, is reproduced here as Table 2.5.

TABLE 2.3
INTERNATIONAL STANDARD CLASSIFICATION
- FIRES AND EXTINGUISHERS

FIRE
TYPE

BURNING MATERIALS - EXTINGUISHANT

- Type A Involve solid materials usually carbonaceous. Fire forms glowing embers. Examples - coal, paper, timber. Use water in spray or jet.
- Type B Involve liquids or liquefiable solids - oil, petrol, and fats. Use water, carbon dioxide or dry powder according to type.
- Type C Involve flammable gases or liquified gases. Use foam or dry powder and water to cool containers.
- Type D Involve metals. Use carbon dioxide and special dry powders - include aluminum and magnesium fires. USE OF WATER DANGEROUS - Special techniques have been evolved for special metals.

(Reference for this classification is "Fire Fighting" - NCB Booklet, Industrial Training Branch, 1978).

A brief comment on fires in the Sydney Coalfield categorized by cause is appropriate.

Mining conditions, methods and equipment employed in UK and CBDC mines are very similar and a comparison of the data shown in Tables 2.4 and 2.5 show that the causes of underground fires follow the same trend.

Clearly, in both the Sydney coalfield and the U.K., conveyors are the principal cause of underground fires. Belt slip and faulty or dirty idler pulleys are particularly critical areas of concern.

Fires resulting from malfunctioning or damaged electrical equipment, including motors and electric cables, are the second cause of fires in UK; this experience is repeated in the CBDC mines.

Experience over the last three years in CBDC mines show that 48% of fire incidents were related to conveyors and 37% to electrical apparatus.

Mechanical causes of fire are generally related to frictional heating and sparking caused by:

- . Collapsed bearings; and
- . Contact with moving parts as a result of damage, wear, overloading (for example).

Cause/Classification	1976	1977
Mechanical Equipment:		
Frictional sparking	1	1
Other	8	10
Conveyors:		
Bottom idler rollers	5	7
Deflector idlers	4	2
Delivery drum		
Drivehead & loop T.U.	4	5
Receiving Section		
Braking devices	2	5
Belt slip	15	
Other		
Locos and Other Vehicles:		
Diesel locos.	1	2
Battery locos	3	6
Other		
Heading Machines		
Pumps	3	4
Switchgear		
Cable joints		5
Compressors		
Other		
Electrical Fires	15	19
Spontaneous Combustion	2	
Contraband	3	
Shotfiring		1
Burning Appliances		2
Miscellaneous/not known		2
=====		
TOTAL	66	71

TABLE 2.4

FIRES IN U.K. COAL MINES 1976 - 1986

CAUSES OF FIRE - CATEGORIES

	1977	1978	1979	1980	1981	1982	1983	1985/86	REMARKS
	1 10	1 6	- 10	11	11	10	7. 7	34*	*Bearing failures
	7 2	} 25	4 3	9 2	} 15	} 30	} 34 (10)	14 6 3 5 1 3 12 3	
	5		1	9					
	5		6 6	4 9					
	2 6		7	1 4		4	3	3 3 1 3	
	4		7	5	4		} 5	5	
	5		2 1	4 1				1 8	
	19	22	18	12	9	13	12	11	
		2		1	5	3	2		
			1						
	1		1						
	2								
	2	2	1	1			1		
	71	63	68	72	62	60	66	121	

TABLE 2.5
FIRE CAUSE/RISK INCIDENTS IN SYDNEY CBDC MINES

<u>Cause Category</u>	<u>Minor Incidents 1985 - 1988</u>	<u>Major Incidents 1973 - 1988</u>	<u>Date Mine</u>
Conveyor Idlers	33	---	
Conveyor Drives	10	1	1984 No. 26
Electrical Motors/ Switches	12	---	
Electric Cables	21	---	
Machinery (other)	2	1	1973 No. 12
Sparking from Rocks	3	2	1975/79 No. 26
Methane Accumulations	3	1	1977 Lingan
Miscellaneous	6	1	1982 No. 26
	--	--	
TOTAL	90	6	

TABLE 2.6
SOURCES OF IGNITION AND FUEL TYPES

SOURCES OF IGNITION	EASILY IGNITED FUELS	FUELS LESS EASILY IGNITED
Mechanical - frictional, sparking/heating.	Methane Fine Coal Dust	Coarse coal fragments Solid coal ribs
Electrical - sparking, overheating	Discarded Paper	Timber
Shotfiring	Diesel, Paraffin, oily waste	fuel oil and Lubricants
Spontaneous Combustion	(discarded oily rags)	Belting, plastics, fabrics
Smoking and Contraband Materials		

There are many references in mining literature which provide detailed case studies of mine fire incidents. The Bibliography in Appendix A refers to a number of these.

Underground coal mining experience shows auxiliary and booster fan installations present serious fire risks.

Spontaneous combustion has not been a significant factor in CBDC mines.

The causes of fires listed above identify sources of heat or sparks but a fire also must have fuel. In recording mine fire incidents and their types or categories, it is important that both the source of ignition AND the fuel or burning materials are identified. The fuel initially ignited often provides the heat to ignite other, less easily ignited fuels. Typical examples from coal mining are shown in Table 2.6.

3.0 OBSERVATIONS AT CBDC MINES

3.1 INTRODUCTION

A list of visits and discussions at the CBDC operations is given below:

. Lingan Mine, August 16 and 17, 1988

- Areas visited - Main conveyor and manriding deeps.
- Advancing longwall sections:
 - . 10 East
 - . 11 East
 - . 7 West
- Development faces:
 - . 8 West
- Salvaging faces:
 - . 9 East
 - . 6 West

. Phalen Mine, August 18 and 19, 1988

- Areas visited - Main conveyor and manriding slopes.
- Longwall sections:
 - . 1 East (retreating)
 - . 1 West (retreating)
- Developments:
 - . 2 West
 - . No. 3 and No. 4 slopes

. Prince Mine, August 22, 1988

- Areas visited - Main conveyor and manriding slopes.
- Longwall faces:
 - . 8 East (retreat)
 - . 6 West (retreat)

- Developments:
 - . East exploration
 - . No. 3 and No. 4 deeps
- Salvage face, 7 east.

. Discussions:

- August 17 - CBDC Loss Control Department
Mr. J. Ashburn, P.Eng.
- August 23 - CBDC Engineering Department
Mr. R. MacLean, Director of Mine Engineering
Mr. W. LeBlanc, Chief Ventilation Engineer
Mr. S. Schwartz, Chief Electrical Engineer
Mr. D. Merner, Manager, Mechanization
- August 24 - Mr. T. Smales, District Manager, Labour- Canada
Mr. D. Payne, Engineer, CBDC (Anydrite Packing)
Mr. S. Forgeron, CBDC Chief Geologist

In addition to formal meetings, discussions were held with other mine management and technical staff.

The remainder of this Section 3, consists of observations and comments regarding underground visits to the CBDC mines. Particular areas of concern which are urgent, and can be corrected in the short term, have been listed as part of the description of the mine. Concerns which cannot be addressed by short term measures have been described in later sections of the report under the appropriate subject heading.

3.2 PREPAREDNESS FOR FIRE FIGHTING

3.2.1 Fire Loss-Control Standards

The Loss Control Department of CBDC has established an extensive and detailed manual of standards for implementing fire-loss control measures at all its operations, particularly at the underground mines. A program is in operation to audit the level of compliance with the standards by means of regular and systematic inspections of work-sites, feed-back reports and recognition for compliance. The manual sets out some requirements for training but the Loss-Control Department does not provide training courses, this is done by other departments within CBDC.

During the mine visits it was observed that ample equipment for fire fighting, (i.e., hoses, hydrants and extinguishers, etc.) was available and that these are regularly checked and maintained at a high level of readiness.

3.2.2 Fire Fighting Training

Management at CBDC accepts the responsibility to "see that a sufficient number of people are properly trained to effectively use the fire fighting equipment provided" but management also should be trained in fire prevention. The CBDC Fire Loss Control Reference Manual, outlines the employees' duties to be alert to fire hazards and to exercise responsibility, within their capacity/authority for fire prevention and fire control.

During the mine visits it was evident that improvements must be made in directing the attention of all employees to the importance of maintaining working places free from fire hazards. This was particularly noticeable in the Lingan Mine where excessive coal spillage had been allowed to accumulate at belt

transfer points where switch rooms were littered with discarded lunch wrapping paper.

Each new employee receives basic training in the use of hoses, hydrants and extinguishers however, it is understood that all employees are trained in the procedures outlined in Element 21, "Water Supply and Fire Protection", item 32 page 15).

Three principal groups of personnel receive fire fighting training; these are:

- . Mine Rescue Teams, trained as part of their rescue training.
- . Mine Supervisors.
- . Workmen.

Apart from Rescue Teams, these employees receive basic training as individuals. Inquiries revealed that training was mainly of a class-room type. Work-site group practices, involving co-ordinated team-work by groups of people who normally work in the same area, were not an established training feature. Neither was special training provided for supervisors. This topic is addressed further in Sections 6.2.2(d) and 6.3.2.

Fire fighting training of work crews is difficult to organize effectively at work sites in an extensive mine. Recommendations at the end of this report will address the provision of special work site training sessions.

3.3 SOURCES OF IGNITION

3.3.1 Incendive Sparking

There have been, in the recent past, a number of gas ignitions due to incendive sparking caused by shearer picks. It is almost impossible to prevent picks striking hard rock bands completely.

However it was noted that steps were being taken to minimize the risks; these were:

- . The introduction of "in-line" and "advanced brushing at the Lingan 7 West advancing longwall face". There are also other advantages to this procedure (such as improved roof control at the roadhead and better access to the face) but the improved ventilation at the face end undoubtedly reduces the risk of methane ignition in this sensitive area.
- . Trials with a new type of shearer drum. It is planned to test an "Extraction Drum" on the Phalen 2 East face. More is said about this in Section 4 which deals with fire prevention.
- . Continued efforts by the geological departments to define known sandstone channels and predict their occurrence in future workings. Production supervisors can, in many cases, adjust cutting horizons to avoid contact with the sandstone.

In the Lingan Mine a crew were observed "dry-drilling". this not only presents an unnecessary incendive sparking risk but reduces bit life and increases airborne dust.

3.3.2 Belt Conveyors

Belt conveyors have already been identified as a common source of ignitions due to the large number of moving parts with potential for frictional heat build-up. The danger is increased by the presence of very fine, easily ignited, powdered coal.

Although the observations made below relate to specific mines and locations, they are also relevant in some degree to belt conveyor installations of all the mines.

Lingan Mine

Coal spillage, particularly under the bottom belt, was excessive and many bottom rollers were prevented from turning. In far too many instances timber had been utilized to support conveyor stands adjacent to stalled bottom idlers. It was said that 60 people were employed to clean up and replace damaged rollers on the trunk conveyors and production panel conveyors (a total distance of about 7500 m). In spite of the large number of people, clean-up and repairs are unsatisfactory. The reasons for this are:

- . Poorly installed conveyor transfer stations.
- . Poorly installed/maintained belt scraper-cleaners.
- . Considerable quantities of water with the coal on the conveyors resulting in:
 - . sludge being carried back into drive units;
 - . transfer stations being wet and dirty; and
 - . slurry pumps having to be used to remove the sludge.

In at least one case a hydrant and fire hose was being used to wash away coal spillage from under a conveyor discharge.

Management should examine this problem in more detail particularly from the point of view of:

- . reducing spillage; and
- . better organization of the personnel responsible for cleaning conveyors.

The problem of excess water on the conveyor belts starts at the faces where large quantities of water are applied at the shearer drums in an attempt to prevent ignitions of methane by incendive sparking and to control airborne dust.

Shearer machines are normally fitted with sprays and the water supply is regulated by a flow-switch which closes the water valve when the machine is stopped. It was observed that the shearer drums were being doused by high volume water jets which continued to deliver water even when the shearer had stopped.

The face workers did not appear to understand that sprays are much more effective than jets in controlling methane ignitions and reducing airborne dust. Neither did they seem to recognize the problems that excessive water created along the conveyor system to the surface.

The shearers should have the proper spray systems replaced and the proper flow-valves put in operation. Final success will depend on worker training and education and a determination by management to ensure that the proper installed systems are not irresponsibly defeated and/or damaged.

A seized roller buried in loose coal is a common cause of conveyor fires. The failure rate of conveyor idler rollers raises the question as to whether rollers obtained locally are adequate. This might be corrected by seeking a better quality product or by CBDC mechanical engineering staff working with the supplier to draw up specifications and quality controls to bring about improved roller performance.

Development conveyors, although often a temporary installation, still require good installation standards if the fire hazard is to be minimized. It was noted that, on one development drive, there were no cover plates installed over the driving drums. This allowed loose coal and dust from the top belt to fall between the belt drive drums creating a potential fire hazard in an area relying on auxiliary ventilation and where, very often,

face workers would have to pass the fire to escape.

Consideration might be given to removal of the heated cabins for conveyor operators. This will reduce the risk of an operator falling asleep on this monotonous job which currently does not require him to leave his cabin.

Cleaning of conveyors has been a problem in many mines for years. Conveyor supports slung from the roof are recommended where roof conditions permit. This makes cleaning underneath far easier either by manual or mechanised methods. It also facilitates the inspection and replacement of bottom belt idler pulleys.

In preparation for the remote operation of the trunk conveyor system from the bunker to the surface, it will be necessary to do considerable redesign work on the transfer points. Excessive spillage presently occurs due to poorly designed chutes, receiving hoppers, and spillage collection systems.

Phalen

During the August 19th visit, the belt of the main cable conveyor broke. The cable conveyor is installed in No. 3 slope; its cable tension unit and belt return pulley are located down-slope of No. 3 East Panel developments. On inspection, the cause of the break was seen to be spillage from a transfer station (possibly at 1 East) being carried back on the bottom belt where it built up between the pulley and the belt. This caused the belt to bulge out from the pulley until it jammed against the structure.

The normal belt slip protection units do not of course operate on cable belt conveyors but it is very important that a suitable

sensor, such as a Pease probe, be installed to guard against a similar occurrence.

Prince Mine

Continuously slung rope structure is used to support conveyor idlers. This makes for easier clean-up and a cleaner installation since no floor supports are necessary.

Conveyor system improvement plans are being prepared in which a crusher and bunker will be installed following which the main deep conveyors will be an automatic, manless operation.

Unfortunately 900 mm (36") gate conveyor belts are used at the Prince mine and they do not have adequate capacity for peak production from the longwall faces. This results in spillage and reduction of production.

3.3.3 Frictional Heating

On Conveyors

The most common sources of frictional heating are found on conveyors; they include:

- . collapsed bearings (mainly of rollers);
- . belt slip at driving drums;
- . belt rubbing on structure; and
- . tail-end units running in loose coal from spillage or bottom belt carry-back.

Most of these problems can be avoided by:

- . good installations;
- . frequent and scrupulous inspections;
- . good maintenance - of protective devices such as belt-slip protection, belt-cleaners, anti-spillage and load centralizing devices; and
- . diligent line structure inspection, maintenance and clean-up.

Reduction of fire risk during operation of underground conveyors, depends greatly on the operating personnel. As dependence on operational manpower is reduced, by the introduction of automatic, manless systems, safe and efficient operation comes to depend more on system design, installation and maintenance - including maintenance of the automatic controls and protective devices.

On Rope Haulages

Rope haulages should not be overlooked as a source of frictional heating. A number of examples were noted (i.e., #10 East-Top-Lingan) where the rope is rubbing and cutting into the steel frame of the hoist itself. There is a need for more rope pulleys and improved standards for hauler installation.

3.3.4 Electrical Heating and Sparking

During the last three years, a total of thirty three minor incidents were recorded, related to electrical motors, switches and cables, (see Table 2.5 in Stage 2 report).

Discussions revealed that problems had been mainly with H.T. cable couplers and, to a lesser extent, with "flashes" at switch gear cable plug sockets, both Lingan and Prince Mine have had experiences of this type.

The high incidence of cable coupler failures is possibly due to thermal cycles drawing moisture into the coupling but the root cause is believed to be sub-standard installation of cable-end plugs and sockets.

The electrical staff at the mines and at Central Engineering are dealing with the cable coupler problem. Alternative cable coupling methods are being examined. There has already been a move from cold poured compounds to hot poured and crimps are being tried in place of screws for securing core connections. Two other alternatives being examined are:

- . non-flammable compounds such as polyurethane resins which are toxic but are being used in other countries and industries; and
- . in-line splicing of cables using isocyanate resin.

Flashes at switchgear were said to have occurred when cables were plugged into damp or wet switchgear sockets. This was very likely because the protective plastic socket caps provided and which prevent moisture from entering unused sockets, had not been used.

It was noted that more care must be taken with trailing cables. In Lingan's 7 West, steel roof supports and heavy RSJ's had been placed on top of cables.

At the face of the main gate a very difficult situation existed, there was barely enough head room for the gate-end boxes mounted over the conveyor and trailing cables were not well organized to provide an efficient handling system that would minimize the risk of cable damage.

3.3.5 Shotfiring

Due to the mechanization of coal cutting and loading and of rock excavation in tunnels and headings, the incidence of ignitions from shotfiring has been greatly diminished but not eliminated. Blasting still has to be done in some areas - usually at brushings and roadheads. It was noted that, in Lingan's 7 West, fourteen blastholes charged with "Monobel" were required to break the stone and more holes were needed to break the coal. It is suggested that Monobel explosive is inappropriate for this work and the number of blastholes required can be reduced by using a different explosive - such as C-X-Lite, a permitted explosive from the same explosive supplier. A reduced number of blastholes, using a more suitable explosive, should reduce the risk of ignition as well as speeding up the work.

3.3.6 Contraband

The prohibition of smoking materials underground is made very clear at all mine entrances but diligence is always required, particularly when mine access is by means of slopes where large numbers of workers enter the mine at one time. This makes adequate personnel searches difficult to carry out. Nevertheless, routine, random, searches at mine entrances are necessary and they should be complemented by occasional random searches underground. These must be done strictly according to Mine Regulations, following a procedure agreed with the Union.

3.4 COMBUSTIBLE MATERIAL

3.4.1 Coal and Coal Dust

The CBDC mines do not have a history of spontaneous combustion and, though the possibility of spontaneous heating can never be dismissed completely, precautionary measures in the Sydney Coalfield need not go beyond those considered necessary as part of normal efficient mining practice.

However the possibility of coal-dust explosions is present particularly in mechanized development headings where there is a higher than usual possibility of gas ignition by incendive sparking. If sparking occurs in the presence of methane and airborne coal dust, the potential for an explosion and fire obviously exists. In the Lingan 8 West Top gate development the atmosphere was very dusty despite the use of a dust collector and overlap auxiliary ventilation system. It may be that, although the equipment installed is adequate, adjustments have to be made until the desired results are obtained.

None of the mines were heavily rock dusted. In many areas the natural wetness prevented a build-up of fine, dry, coal dust. However regular, liberal applications of rock dust to roof and sides not only adds to safety by reducing dust combustibility but also creates a better working environment by improving illumination. It was noted that trickledusters were not used for rock dusting, reliance being placed on week-end dusting using rail mounted, mechanical, rock-dust spreaders, mainly in the main manriding slopes.

Rock dust can be distributed throughout the mine, via pipes from a bulk storage tank. The rock dust is blown through the pipes by air blowers. The storage tank may be at the surface or at a prepared underground site conveniently located; the system would have to be designed to the needs of the particular mine. The rock-dust is blown into the air from the pipe system at numerous strategic locations.

Advantages claimed for the system are:

- . it is economical on manpower; and
- . it relies on a light but constant application of rock dust which results in a more homogeneous dilution of the coal dust.

Objectors claim that the rock-dust trickling into the air stream creates a very unpleasant dusty atmosphere. Nevertheless the systems is widely practiced in mines in U.K. and North America and its application might be considered by CBDC as being a more effective method of dusting.

3.5 VENTILATION

At Lingan a contingency procedure has been developed which enables the intake air-flow down the main conveyor deep to be reversed should a conveyor fire break out. The procedure calls for ventilation doors in the No.8 East Bottom Level (between No.3 and No.4 deeps) to be opened and an inflatable seal inserted at the top of the Main Conveyor Deep.

During the mine visits it was noticed that the No.8 East Bottom Level doors were extremely difficult to open and close and that the door to the return airway (just above the bend in the main roads) was not well maintained. In addition, the inflatable plug was stored in a warehouse in Glace Bay instead of at the mine site.

The engineering, planning and trials which went into developing this contingency procedure are commendable; its successful implementation in an emergency should not be jeopardized by lack of preparation.

3.6 GENERAL TIDINESS

Most observers of operations at Lingan would notice the untidiness. Earlier, mention was made of the switch rooms and resting places. Conveyor clean up was seen to be inadequate in many areas.

The presence of inflammable material, discarded and unsuitably stored, is too common. Items such as 5 gallon oil cans, both full and empty, were observed in many places. Boards, wedges, cables etc. were seen lying along the sides of roadways. Most of these items, but particularly oil, are sources of fuel in the case of a fire.

A systematic clean-up program is required to correct these conditions.

3.7 FIRE CAR

The fire car located on the surface is kept behind the main haulage engine. To place it on the rails to go into the mine requires opening doors and the use of a forklift to transport the fire car to the main marshalling yard at the top of the supply yard. It is recommended that the car be permanently kept within the marshalling area.

3.8 DISCUSSIONS WITH TECHNICAL PERSONS

3.8.1 Ventilation Reversal

Plans have been prepared by the Engineering Department of CBDC to reverse the direction of ventilation in the main conveyor deeps in all three mines. In each case three moves will be required:

- . open ventilation doors at the inbye end of the main conveyor to permit air from an adjacent intake slope to pass to the conveyor road.
- . open ventilation doors between the conveyor road and the main return as close to the fan as possible.
- . insert an inflatable seal or close a preconstructed door in the portal of the conveyor slope.

Sites have been selected for all these requirements, and some tests were made during week-ends to check the effectiveness of the change.

Experience during fires at No. 26 Colliery and Wilberg, Utah, has shown that there is little warning of conveyor or compressor fires; it is therefore vital that the air-reversal moves be made effectively, quickly and by remote control from the control room. On a manless conveyor system, the first indication of a fire will probably be an alarm in the control room from a carbon monoxide detector along the conveyor slope. Few men will be in the vicinity to check the cause of the alarm. With air velocities of about 4 metres per second, carbon monoxide would travel the length of the conveyors at Lingan and Prince in 12 minutes, and reach the faces between two and ten minutes later. THERE IS NO TIME TO LOOSE.

There may not be time (and it may not be possible) to reach the inbye ventilation doors and open them. Someone also has to go and open the ventilation doors to the main fan. To move the inflatable seal into position and wait for it to be inflated is also time consuming.

It has already been shown that the air reversal procedure works; it is now recommended that the inflatable seal be replaced by a permanently installed (normally open) steel door(s) arrangement and that all ventilation door openings and closings be activated from the control room using electro-mechanical/hydraulic systems or electrically initiated, compressed air systems with "at-site" pressurized back-up tanks.

The cost to design and install such a system at each mine will vary but a system could cost up to \$200,000. However, to help protect so many people and avoid the magnitude of losses such as the No.26 Colliery fire incurred, this is not an excessive cost and should receive a high priority.

Once in place, the system should be operationally checked at regular and frequent intervals and Control Room Operators should be trained as to when and how it is to be initiated.

3.8.2 Rock/Gas Outbursts

In discussions with the CBDC Chief Geologist, it was reported that most of the rock/gas bursts occurred between 1980 and 1984 at No. 26 Colliery in the vicinity of the arch deeps. The first occurred at a depth of 700 metres. A total of 38 incidents have been recorded (though only three major incidents were reportable to Labour Canada).

These outbursts in themselves are not a direct fire risk. However, they do occur in headings where mechanized cutting is carried out, where ventilation is dependent on auxiliary fan systems and where there is only one exit from the face. The principal danger is the sudden release of unusual volumes of methane at the same instant as a violent energy release from bursting sandstone rock. The gas may be ignited by machine picks striking falling rock.

All outbursts occurred in the sandstone above the coal and were accompanied by emissions of methane. None occurred in either coal or shale. The sandstone itself is impermeable and contains up to 20% illite and chlorite.

The phenomenon is thought to be due to overstressed strata. In cored holes it has been noticed that discing takes place in areas prone to outbursts. All outbursts have been within 10 feet of the top of the coal. The antidote was to blast the coal to trigger the outburst while no men were present.

In Lingan it is planned to drill horizontally ahead of the prime development, far enough to accommodate one year's advance. A drill will be used to core the sandstone above the coal. Careful observations regarding type of strata, gas make etc. will be made. The work is planned to be done by CBDC staff and workmen. Some assistance from CANMET might be considered.

3.8.3 Stoppings

A program is underway at Lingan and other mines, to eliminate wooden stoppings, particularly those separating the main slope intakes and returns. In general the elimination of wooden stoppings is progressing well. However, it should be noted that the breeze block type of stopping with a minor amount of keying

into the strata, especially coal, does not represent a very strong barrier to fire. In coal, a fire will normally eat round the edge quite quickly. Section 6.4.3 (c) Doors/Stoppings, deals with this aspect in more detail.

3.8.4 Replacement of Wood

Wood has been used in mines for years because it is comparatively inexpensive, can be handled easily and can be seen and heard if it is in the process of failing. Today wood is mainly used in the form of chock blocks to strengthen dirt packs and to provide a covering and a cushion behind steel arches or girders. In addition it is used for rail ties, some ventilation doors or stoppings, steps, conveyor cross-overs, notice boards or signs, conveyor support etc. A CBDC committee has been established to prepare a program to systematically replace wood in most of these areas. A list has been drawn up of items to be replaced, together with a time table for compliance and responsibility for implementation. A copy of this program is enclosed in Appendix A. The Corporation is to be commended for this positive move towards removing combustible material from underground workings.

4.0 PREVENTION OF FIRES

4.1 INTRODUCTION

Three ingredients are required for a fire, namely a fuel, oxygen and a heat source. To minimize the risk of a mine fire, the use of combustible fuel materials must be reduced and where possible eliminated; and sources of ignition must be eliminated.

In this section an examination is made of the overall planning procedures required to reduce the risk of fire in CBDC mines. Emphasis is placed on the two areas previously identified in Sections 2 and 3, namely conveyor and electrical installations.

Three management/personnel components are important to the success of these preventative measures:

- . High quality management and supervision in all aspects of the mine operation;
- . Sound mine planning and detailed engineering;
- . Education and training of all underground personnel in the reduction or elimination of fire hazards (coupled with fire combat practice) drawing the attention of all employees to the importance of their role in bringing this about.

4.2 MINING METHOD

Only two methods of mining are feasible in the greater part of the Sydney coalfield undersea reserves:

- . advancing longwall; and
- . retreating longwall.

Given the mining conditions encountered, the choice between these systems will be based on general considerations of safety, cost and productivity rather than being confined to the particular risk of heatings and fires. In terms of the fire risk inherent in each of the methods, a comparison does not lead to a conclusive choice of either.

For instance, it is true that retreating longwall generally reduces the risk of a heating developing in the gob, but spontaneous combustion has not been a critical problem in the CBDC mines, therefore this is not a significant factor.

Ventilation of a face in a gassy seam is generally more efficient in a retreating longwall than on an advancing wall. Consequently the danger of a gas ignition leading to a fire is reduced. On the other hand methane drainage is more difficult on retreating faces. In summary, it can be said that though retreating longwall systems are usually more efficient and operationally safer than advancing faces, they do not have a marked advantage in terms of fire risks.

4.3 CONVEYORS

Earlier statements and statistics in this report show that conveyor problems are responsible for the greatest number of fire incidents in CBDC mines. It is therefore appropriate to discuss the following aspects of conveyors:

- . Design
- . Installation
- . Maintenance
- . Cleaning
- . Inspection.

4.3.1 Conveyor Design

4.3.1.1 Capacity

The installation of conveyors with sufficient capacity to handle peak tonnages is critical not only for efficiency but also to reduce spillage and consequently fire risk. Designed conveyor and transfer station capacity should be sufficient to handle all the mineral delivered onto it (including load surges) from such sources as:

- . longwall shearers;
- . advanced heading machines;
- . outbye repair works and excavations; and
- . development heading machines.

Sample figures for a longwall panel alone might be:

. shearer cutting 2 m seam	20 tonnes/min. (peak)
. advance heading machine	3 tonnes/min.
. brushing with scoop	<u>2</u> tonnes/min.
	25 tonnes/min. or
	1500 tph

This represents the tonnage which a longwall gate belt may be required to handle. A conveyor design manual will indicate that a load of 1500 tonnes per hour cannot be handled by a 915 mm (36 inch) belt at speeds up to 3.5 m/s (700 ft/min), the most that can be expected is about 900 tph.

There are a number of conveyor installations in CBDC mines which do not have the capacity to handle peak tonnages from the faces they serve. This defeats all efforts to maintain clean conveyors and results in damaged idlers, excessive spillage and, consequently, fire hazard conditions.

The consultants did not spend enough time in the CBDC mines to analyze the situation in detail, installation by installation. It is suggested however that an extensive review of the existing conveyor systems in all mines should be undertaken by CBDC staff to determine which conveyors are below capacity and to draw up a schedule showing how the problem can be overcome. Corrective action will be a combination of;

- . wider belts;
- . increased belt speeds;
- . improved coal transfer arrangements;
- . improved conveyor maintenance; and
- . feeder breakers and bunker capacity to reduce peak loading.

Although 1050 mm (42 inch) conveyors are already being installed in some places, a conveyor capacity survey is critical since even these belts may prove inadequate. It is worth noting that in Australia and U.S.A. some longwall installations on retreat faces now use 1400 mm gate belts running at 3.5 metres per second. In thick seams in Australia 1600 mm belts are used. The shearer horse powers on these faces are higher than those in CBDC mines but the level of installed conveyor capacity indicates the extent to which other mines are prepared to go to provide adequate coal clearance and by so doing to reduce fire risks.

4.3.1.2 Headings

In development panels up to 3 machines could be loading onto one conveyor. Because these machines are only cutting 20 to 25% of the shift, for long periods the conveyor may be under loaded yet incapable of handling peak loading. Excessive spillage and subsequent clean up may be avoidable by utilizing portable bunkers.

4.3.1.3 Conveyor Control Systems

Servo-systems can be used to automatically regulate bunker discharge rates to meet design criteria regarding feed onto conveyors. This is normally only done with long term installations but it might be considered as an extension of the scheme for remote operation of conveyors, planned to be introduced in the Corporation's mines. (Lingan, due to its shorter life may be an exception to this).

4.3.1.4 Conveyor Belting

Standards have been set in all countries to reduce the risk of conveyor belting catching fire. Simply stated the procedure involves a flame test in which a lighted gas jet is applied to the belting; the burning must cease after the removal of the flame. The second procedure is a drum friction test carried out under controlled conditions in which the belting must not catch fire. Manufacturers have their own test facilities where trials are undertaken prior to submitting specimens to be approved by Government authorizing agencies.

Two main types of conveyor belts are produced for use in underground coal mines:

- . Neoprene based types, with styrene and butadiene (SRB).
- . Polyvinyl chloride types, including impregnation of the fabric (PVC).

The PVC type is popular in Canadian coal mines due to effectiveness and price.

Since all conveyor belting in CBDC mines must conform to Canadian Approval standards this is not seen to be an area for CBDC involvement in research and development.

4.3.1.5 Chutes

Correct design of transfer points and conveyor chutes is important if coal spillage (and fire risk) is to be minimized. Each transfer point will require a chute of different design depending on:

- . the width of conveyors;
- . the angle of delivery;
- . the rate of feed; and
- . the height difference between the delivery and receiving conveyors.

It is proposed that the Corporation examines its design and installation standards for coal transfer between conveyors. It should carry out an evaluation of each underground transfer point during the survey of underground conveyors mentioned previously. Provisions for dust suppression must also be included in transfer point design. Scraping off fine coal which adheres to the bottom belt behind the delivery drum is an important design feature. If this function is not well performed fine coal is deposited from the belt as it passes through the drive pulleys and loop take-up. Attention should also be given to the mechanical pick up of scraped fines and spillage by auxiliary scraper chains which discharge the spillage back onto the belt.

A degree of standardization should be aimed for in transfer station design.

4.3.1.6 Line Structure Support

Support of the structure is important. The Corporation currently uses ground-mounted structure in almost all installations. This practice has several disadvantages in respect of fire hazards:

- . Bottom idlers are close to the ground making cleaning fines and spillage more difficult.
- . Cradles for bottom idlers are supported at the ends with blocks of ash-brick, or sometimes wood. These provide a flat surface where the coal fines build-up and come in contact with the bottom idler.
- . If an oil seal leak develops on a roller, a dry bearing can heat up and initiate a fire. While bearings also fail on conveyors slung from the roof, they are more likely to be noticed and, being higher and clear of supports, a hot roller is less likely to be buried in dry coal fines.

In considering the use of conveyors slung from the roof, the slings must be adjustable to cater for roof movement and support distortion.

4.3.1.7 Idlers

A large number of conveyor idlers used by the Corporation are made locally. It was learned that the life of these idlers is unsatisfactory due to premature failure of bearings and seals. In Section 3.3.2 it is suggested that CBDC Engineering staff seek to obtain better quality idlers by helping the local supplier to develop a better design and quality control system. Alternatively, it may be necessary to select another supplier.

4.3.1.8 Belt Slip

Belt slip occurs when there is insufficient adhesion between the driving drums and the belt. The resulting slippage leads to frictional heat being generated, often hot enough to melt plastic from the belt, start smouldering of the belt carcass, ignite contiguous coal dust and generate dense smoke.

Belt slip can be caused in numerous ways, for example:

- . insufficient belt tension, overloaded belt or a combination of the two;
- . worn out or wet lagging on the driving drums; or
- . a jammed or trapped belt - often the result of spillage being carried back on the bottom belt into a return end unit.

All conveyor drives should be fitted with belt-slip protection devices and in CBDC mines these devices are in fact provided. However, the list of minor incidents (Stage I) shows that six and possibly nine incidents were the result of belt-slip. This seems to indicate that belt-slip protection devices, though in place, either are not working correctly or have been rendered inoperative, indicating that maintenance inspections and repairs are inadequate.

A detailed review and inspection of all sequence controllers and belt-slip protection systems should be instigated and any necessary corrective action taken.

4.3.1.9 Conveyor Brakes

Several fires have been reported which have been caused by faulty brakes. Brakes are normally of the thruster activated type on the high speed part of the transmission. Careful inspection and good maintenance is the remedy.

4.3.1.10 Conveyor Transmissions

There are still reports fires at fluid couplings used between the motor and the drive gear box. Small units normally use the traction type couplings which are filled with water, or soluble oil. Large units use the scoop type couplings, usually filled with phosphate ester solution.

These designs have removed most of the fire dangers associated with the discharge of hot oil. Cleanliness around the couplings is, however, still very important.

These comments apply to all applications of hydraulic couplings throughout the mine, not only to those on conveyor drives.

4.3.1.11 Fire Suppression Systems

Fire suppression systems are important to the safety of a conveyor drive installation; they can prevent a minor fire developing into a major incident.

The suppression system comprises a series of foam or water sprays positioned over the conveyor drive, delivery and loop. The foam/water supply to the sprays is controlled by a fusible plug or link which melts when the temperature rises above a pre-determined level. This opens the valve and the drive installation is deluged with water or foam.

Automatic operation is necessary for manless systems. Fusible plugs may be replaced by carbon monoxide detectors, which activate the system. More is said about this in Section 6.4.2.

4.3.1.12 Remote Operation

Most mines now employ conveyor systems which are remotely operated. Some have computerized systems which control bunkers, shaft hoisting etc. In CBDC the "MINOS" Monitoring and Control System from the U.K. has been selected for all three mines. The extent of the application varies from mine to mine.

The major conveyor control functions provided are:

- . Start
- . Stop
- . Indication of start-up (audible warning)
- . Indication of belt slip on the drum
- . Indication of broken belt
- . Indication of belt misalignment
- . Indication of torn belt
- . Indication of blocked chute
- . Indication of motor temperature
- . Indication of certain bearing temperatures
- . Indication of smoke (now usually replaced by a carbon monoxide detector)

Using this system the status of each conveyor drive is known in the surface control room. The reliance on remote monitoring and control adds greatly to the importance of maintenance and equipment reliability.

4.3.2 Conveyor Installation

The main requirements for a good conveyor installation are:

- . Good foundations or overhead supports.
- . A well aligned conveyor drive and line structure.
- . Uniformly graded structure.
- . Adequate clearances.
- . Well lit drive house and transfer point.
- . Cleanlines.
- . Well designed and installed discharge chutes.
- . Well made belt joints.
- . Efficient dust suppression and belt cleaning systems.

The installation work must be carried out to a high standard to ensure a safe and efficient conveyor operation.

4.3.3 Maintenance and Cleaning

4.3.3.1 General

Maintenance and cleaning are considered together because they are so closely connected. For example, if the belt wipers are kept in good condition, coal fines will be deposited in one place, where they can be handled by a mechanical system rather than accumulating at each bottom idler over a long installation. Similarly, spillage can be greatly reduced by well designed chutes and well maintained receiving hoppers. Plows, wiper blades, hopper skirts and load centralizers should be kept in good working order, being replaced when worn.

Details of maintenance work carried out should be recorded in order to identify recurring problems.

4.3.3.2 Bottom Idlers

Faulty bottom idler rollers are a common cause of conveyor fires. The rollers are light metal cylinders, 100 mm or 130 mm in diameter, rotating around a fixed axle by means of a bearing at each end of the cylinder. The bearings are the key feature of the idlers.

Most conveyor manufacturers provide idlers in which the bearings are greased and sealed for life. The life of the idler is determined by how long the bearings last. On extensive or long conveyor systems, where there are approximately 335 top idlers per 1000 m and 670 bottom idlers per 1000 m, if idler roller life is too short, it becomes a major problem to keep all 670 bottom idlers per 1000 m in good working order.

Bearings are in continual use under fairly severe conditions. If the seals fail due to abuse, inadequate design or undetected manufacturing flaws, then dirt and dust enters the bearing housing and the bearing collapses or siezes..

If it collapses, the idler continues to rotate and friction at the bearing causes it to wear and heat up. Often, particles of hot metal fall into accumulations of coal dust and a fire may develop. Also, the friction at the bearing causes the end of the roller to heat up and if this is in contact with loose coal and dust spillage, it too can develop into a fire.

If the bearing siezes, the idler roller no longer turns but the belt continues to run rubbing on the non-rotating roller. This heats up the roller very quickly, sometimes to temperatures approaching a dull red heat which can ignite coal dust and spillage.

Clearly two important features of fire prevention on conveyors are the maintenance of idlers and the absence of spillage.

In the U.K. coal mines, 45% of all underground fires, over a 20 year period, were attributed to faulty conveyor idlers and of this 45%, 92% were bottom belt idlers.

4.3.3.3 Mastabar Conveyor Heat Detector

The MASTABAR MINING E has developed a system which can detect the location of "hot-spots" on the bottom belt of a conveyor.

After a belt is stopped, heat from damaged idlers passes into the belting to create "hot spots". These are detected when they pass by heat sensors after the belt is re-started.

The Mastabar System consists of a pair of infra-red heat sensors, located under the bottom belt, which feed signals into an intrinsically safe micro-processor. The system can indicate:

- . the location of the hot idler pulleys; and
- . identify those idlers whose operating temperature suggests the approach of complete mechanical failure.

A "Mastabar" unit is to be installed by CBDC and if it proves successful more will be purchased.

The benefits of this device may be appreciable. The "Mastabar" Brochure is included as Appendix B of this Stage II Report.

It must be emphasized that the "Mastabar" device of itself, IS NOT A MEANS OF PREVENTING CONVEYOR FIRES - IT IS A MAINTENANCE TOOL. It is the maintenance and replacement of faulty idler rollers that reduces the incidence of conveyor fires. It should be appreciated that the effectiveness of the "Mastabar" may put a strain the resources of maintenance crews and could present temptations to switch-off or defeat the equipment because, in effect, the equipment draws attention to short falls in idler roller performance and efforts to replace faulty idler rollers. It may highlight the need for better quality idler rollers.

4.3.3.4 Conveyor Clean-up

The first way to minimize clean-up difficulties is minimize spillage and the deposit of fines carried back under the bottom belt. These items have already been addressed but may be restated in summary as:

- . increased conveyor carrying capacity;
- . reduced use of coal wetting; and
- . properly designed and installed transfer points which include:
 - mechanized handling of spillage; and
 - effective bottom belt cleaning.

Conveyor clean-up in CBDC relies on manpower using hand tools. The work is laborious, uninteresting and can never be successfully concluded.

However, the work can be less laborious when the installation standards are good. Where headroom allows, structure slung from the roof affords better access for mechanized clean-up using

small bucket loaders. Spillage pick up using vacuum cleaners is being tried in some places. To be effective in CBDC mines, the vacuum system would probably have to be a mobile unit that could be moved alongside the conveyor and emptied once per shift or a gate end vacuum unit and cyclone dust extractor with vacuum pipes along the conveyor. A suction head and 50 m hose could then be connected to the vacuum pipe line via "quick-couplers" at 100 m intervals. At present an apparatus of this type is not available for coal mine application however components are available for a system of this nature to be developed.

4.3.3.5 Conveyor Patrol

There are three activities related to conveyor operation:

- . transfer point/conveyor drive operation;
- . conveyor clean-up; and
- . conveyor maintenance.

Transfer point/conveyor drive operation can be done successfully by remote control assuming that the transfer station is well designed and installed; conveyor clean-up can be minimized. Conveyor maintenance is ongoing and adequate labour resources must be assigned to this task.

Remote control of conveyor systems implies the removal of operating personal from transfer stations. Problems will still arise from time to time, such as blocked chutes therefore there must be conveyor patrols who can go and correct the problems and ensure that all is well along the conveyor lines. Their job is to carefully examine conveyor lines seeking signs of heating, faulty idler rollers, misalignment or damage of structure and belt as well as accumulations of spillage. They are also available to investigate and attend to malfunctions recorded by

the monitoring and control system. The Conveyor Patrol program should ensure that conveyors are examined:

- . during every operating shift; and
- . in every shift which follows a conveyor shut-down, at week-ends and holidays for example.

While patrol personnel can assist with an emergency clean-up or changing an idler roller for example, it is important that their primary function as conveyor inspectors and trouble-shooters is respected and that they are not diverted to general clean-up and mechanical repairs.

Patrol personnel might carry infra-red heat detectors on their inspections and they should complete conveyor inspection reports. All those employed on the operation and maintenance of conveyors should have been trained in fire fighting particularly as applied to the detection and treatment of "hot-spots" and smouldering fine coal which might be discovered underneath conveyor belt lines.

4.4 ELECTRICAL FIRE INCIDENTS

4.4.1 CBDC Experience

The incidents of electrical fires or "flashes" listed in the "Minor Incidents" between April 1985 and April 1988 numbered 34; 17 in Lingan, 11 in Prince and 4 in Phalen, (there was one other in Donkin - now temporarily closed).

The equipment associated with these was:

Cables	14
Switchgear	12 (plus 3 more at surface)
Cable Couplers	<u>6</u>
	32 (underground)

Add flashes and burns to electricians, 2.

The incident descriptions are very brief and only allow general observations to be made, however attention is drawn to two points which must be considered significant:

- a) 53% of the underground incidents occurred in Langan as opposed to 34% in Prince and 13% in Phalen; and
- b) high proportion (46%) of the incidents were related to switches (if the problem of cable couplers is treated as a separate issue). In the usual operations of a mine one expects cable faults - normally trailing cables - to far exceed switchgear faults. In the CBDC mines they are almost the same.

These observations suggest, first of all, that special attention should be paid to improvements at Langan, and secondly, that installation, operation, and maintenance of switchgear should also be receiving special attention.

4.4.2 Trailing Cables

The most vulnerable item of electrical equipment in a mine is the trailing cable. Handling and storing procedures should be established at all mines and those who use the cables and supervise their handling should know what these procedures are. Regular inspection and testing of trailing cables is part of the

regular preventive maintenance program and periodic checks should be made to ensure that these are being effectively carried out and logged.

During the recorded 3 year period there were more electrical incidents with trailing cables than with any other single item of equipment - of any kind. This is mainly an operational problem and it should be remembered that the ultimate failure and rupturing of a cable may occur some time (perhaps days) after the actual damage occurred.

To minimize these problems the following steps should be taken:

- a) Review the design and use of the cable handling system at each machine. Even the best cable handling systems will not prevent damage if they are not used correctly or are abused.
- b) Institute daily external examination of all trailing cables by competent authorized persons who will file a report. This is in addition to the Equipment Operator's Report, the one who has the first level of responsibility, on his own shift, for examination and safe use of the trailing cable.
- c) Electrical staff must frequently check the switchgear protective systems in order to keep cable fault magnitude to the very minimum possible.
- d) All cable plugs and half cable couplers in service should be checked periodically to make sure that the back end clamping arrangements are tight. This is in order to maintain integrity of flame proofing and to prevent tension being applied to the conductor connections.

- e) Spare cables should be hung up and the equipment with which they may be used identified; the size of conductors is an important limiting factor. Out of service cables must have their ends protected by covers to prevent dust and moisture entering the plugs and sockets.
- f) Damaged cables withdrawn from service must be clearly marked "out of service" and rendered incapable of further use before repair. A simple way to do this is to insert short 10 mm (3/8 in.) wood dowels into the pilot socket; this prevents the power being applied to the cable.

4.4.3 Cable Couplers

Two of the reported incidents are recognized as occurring at high tension couplers. These usually do not have the same degree of exposure to external damage as trailing cable couplers since they are compound filled and have a rubber type gasket between the two halves. Failure could be due to unsatisfactory filling of compound, loose grub screw connections (if not of the compression type) or loosely fitted connector pins which would trigger off heating and eventual deterioration of the insulation.

All types of couplers should be hung clear of the floor and suspended in a satisfactory manner, especially clear of wet floor and water.

Connection of trailing cables and couplers is usually performed by non-electrical personnel; they must be continually reminded that cable plugs and couplers must be perfectly clean and dry before coupling is attempted.

4.4.4 Switchgear

The number of switchgear incidents appears to be unusually high when compared to vulnerable trailing cable incidents (12 to 14 respectively).

Damage to switchgear, in 3 surface incidents (2 at Lingan, 1 at Phalen) is symptomatic of the rupturing capacity of the switchgear being inadequate.

Practically all other faults appear to be switchgear problems. Maintaining the integrity of switchgear is most important and frequent inspections must be made to ensure that all bolts are tight and air gaps meet specification standards. The report of loose bolts in one incident shows that these standards may not always be met. Careful examination and diligent implementation of the maintenance scheme is essential. Indications are that the frequency and/or quality of examinations and maintenance are inadequate; this possibility should be investigated and, where found necessary, corrective measures implemented.

4.4.5 Flashes and Burns to Electricians

Unfortunate incidents of this kind usually relate to electricians who are over zealous in trying to get repairs done as quickly as possible, often under pressure from production supervisors who are not as familiar with the equipment as they should be. Upgrading and refresher training of Production Supervisors may be beneficial because, in these types of incidents, more time and production is lost trying to take "short-cuts" than is incurred when the work is done properly and safely. Electricians must be made familiar with the details of the equipment and how safe trouble shooting procedures can be followed.

4.4.6 General Comment

All "flashes" and "sparks" produced by the malfunction or failure of electrical equipment have the potential to result in fire or ignition of methane and their causes should be examined and carefully analyzed. Very often the misuse or abuse of equipment by operating personnel has been the root cause of the electrical fault. It is therefore suggested that investigations into this type of incident be done by an electrical engineer, an experienced mining supervisor and the Safety Engineer, jointly. The conclusions of the investigation should include estimates of production and material losses and make recommendations to prevent a recurrence.

Determined implementation of remedial and preventive measures should be taken. Any of the incidents discussed above had the potential to initiate even more dangerous conditions therefore the results of investigations and resulting action must be drawn to the attention of mine personnel to help educate them to the dangers, dispel attitudes of complacency and remind them of their shared responsibility for fire prevention.

4.5 COMBUSTIBLE MATERIALS FOR ROADWAY SUPPORT

4.5.1 Main Conveyor Roads

The main roadway development drivages at CBDC mines follow the coal seam, large coal pillars are left at each side. Roadway support is normally provided by steel arches at 1.0 m spacing, strengthened by steel ties and backed by corrugated metal sheets. Wood is wedged behind the sheets to secure the arch and support the strata, particularly at the shoulder of the arch and over the arch's crown.

The space behind the metal sheet, which usually contains some wood, could be filled by pumping in a non-flammable material to fill the voids and envelope the existing timber before solidifying. Examples of this pumped material are the patent, gypsum based, compounds such as:

- . Mandoseal; and
- . Anhydrite

as well as cement grout types (such as "Pozament" products) to which fly-ash may be added for extra bulk.

To start back filling the arches in all the existing roadways would be so slow, costly and operationally disruptive that it could not be justified. However, it may well be cost effective in certain fire risk zones such as the vicinity of conveyor drives and permanent conveyor belt return units.

4.5.2 Panel Intake Roadways

Again, support is usually by means of steel arches backed by metal sheets. However, in panel intake roadways, additional factors have to be considered:

- . There is greater strata load on the arch supports due to the front and back abutment pressures (from retreating and advancing longwall faces respectively); and
- . On advancing faces, the gob sides of the roadway are supported by wooden cribs or chocks built to support the roof and prevent the gob from breaking right up to the edge of the roadway.

This means that there are considerable quantities of combustible material (i.e., chock wood and boards) used to support these roadways along the edges of the gob. To reduce fire risks a number of things can be tried:

- . Change the system so that less wood is needed; (i.e. change from advancing to retreating longwalls and eliminate the need for gob side chocks/cribs).
- . Replace wood by some other material; (i.e. replace wood chocks by Anhydrite based pump packed material).
- . Apply fire retardant coatings to exposed wood or coal surfaces.
- . Impregnate timber with fire retardant chemicals.

Impregnation of timber is an effective method; a product called "Fyrprufe" has been used in UK coal mines. Its chemical composition is a solution of:

- 89% Ammonium Sulphate
- 5% Ammonium Phosphate
- 2% Sodium Chromate
- 4% Sodium Fluoride

Other organic compounds have been developed for timber impregnation but have proved too expensive to be cost effective.

Fire retardant coatings in mines usually consists of spraying exposed timber with a thin slurry of water (1 part), limestone dust (4 parts), sodium silicate (1 part); the water evaporates leaving a thin, crusted, coating covering the wood. Coatings of 1.1 mm (on hardwoods) and 3.2 mm (on softwoods) have been found necessary to retard (but not stop) fire progress. The system is not widely used because, in practice, the application of the coating is difficult, the slurry runs off the timber and does not adhere readily to dusty, dirty timber. ("Fire Retardant Treatments for Mine Timbers", D.G. Wilde, The Mining Engineer, March 1972).

To seek alternatives to combustible materials such as timber, by evaluating non-combustible materials which can perform the same function at a similar cost, is a practical approach to the problem and can, in many cases, lead to cost savings. The Management of CBDC has set up a task-force devoted to this and there is an ongoing program of combustible material replacement which will help reduce the spread of underground fires. (See Appendix A, "Recommendation for Combustible Products Used Underground - Elimination/Replacement").

One of the most significant objectives of the "timber replacement" program is to find an alternative to the use of the wooden chocks at the gob side of advancing faces. A major problem with these chocks is that they do not form a seal so that air leakage across the gob makes it difficult to maintain methane free conditions at the face, especially at the return end. Attempts are being made to overcome this problem by pumping in patent cement grouts or fillers into a plastic membrane located between two rows of wood chocks. Various fillers have been tried, such as "Astracem" which are gel-like substances with a 90% water content. Trials with "Astrapak" from "Pozament" (U.K.) brought about big improvements in the ventilation. Tracer gas tests showed that 86% of the intake air entering the panel reached the face. However, it is very difficult to obtain an airtight seal between the roof and the top of the pumped material.

4.5.3 Introduction of Anhydrite Packs

The system described above, though effective in improving ventilation, does not avoid the use of wood chocks. Trials are now being conducted with non-combustible Anhydrite which is a much stronger material and which it is expected will be capable

of supporting the roof without the use of chocks. A pack cavity is formed by erecting temporary retaining walls of wire mesh and plastic. The cavity is then filled by blowing in Anhydrite wetted at the nozzle of the placing hose. The Anhydrite sets into a solid block to provide both a seal and a roadside support. The Anhydrite can be mixed with fly-ash to provide an inert bulking material.

Trials at CBDC have shown:

- . Anhydrite has good setting properties.
- . A mixture of Anhydrite and fly-ash is also satisfactory with peak strength occurring when fly-ash is about 5% (by weight) of the Anhydrite/fly-ash mixture.
- . Compressive strengths reach about 38 MPa (= 5,500 psi).
- . The Anhydrite can reach the same maximum strength as "Astrapak" in 11 to 12 hours and after this Anhydrite eventually achieves a much higher compressive strength.
- . That Anhydrite can replace the chock wood and Astrapak system at about 50% of the cost.

Plans are underway for CBDC to acquire an air blown Anhydrite transportation system from Germany. With this equipment the use of Anhydrite will be extended. At present the Anhydrite is imported from U.K. but there are deposits of Anhydrite in Cape Breton. There have been some preliminary studies that suggest that Anhydrite from a source some 45 km from Lingan could cost between \$60 - \$135 per tonne delivered, depending on the quantity, however more investigation is needed to:

- . Define the quantity, quality and accessibility of local reserves;
- . Examine processing required to achieve a suitable end product;
- . Test the strength of pack supports made from the local product;
- . Determine what constraints might be imposed by the "Patents" of foreign manufacturers.

If Anhydrite packs are introduced to permit the re-use of panel roadways where retreat longwalls are used (as is being considered for the Phalen mine) it is most important that the packs have the strength to withstand the compressive loads of the strata and the pack must be sized accordingly. This applies equally to roadside packs of an advancing face where Anhydrite is used to replace the wood chocks.

Face production must not be restricted by pack construction so it is important to ensure that the equipment used to place the Anhydrite has sufficient capacity to extend the packs at a rate commensurate with the rate of retreat (advance) of the face.

4.5.4 Return Airways

Conveyors, are not often placed in return airways therefore there is a lower expectation of fire in the return. What is more, smoke and fumes from return airway fires are not carried directly into the working faces and unpolluted intake airways afford an escape route. For these reasons fire-proofing efforts are mainly concentrated on intake airways, particularly those in which belt conveyors are installed.

4.6

FRICTIONAL IGNITIONS ON PRODUCTION FACES

Recent experience in the Sydney Coalfield is that frictional ignitions on longwall faces have caused two serious fires. On both occasions methane was ignited when the shearer drum was cutting in silicious rock. Three developments which should reduce the risk of this type of fire are described below.

Firstly, geological work now being done by CBDC, measures known sandstone channels and extrapolates their occurrence in future workings. This is of considerable help because it enables projected face layouts to avoid the worst areas and it indicates the zone where close supervision and caution should be exercised to avoid cutting into silicious rock bands.

Secondly, an improved type of shearer drum, the "HD Extraction Drum" is to be tried on the Phalen No.2 East face. Features of this drum are illustrated in Figures 4-1 and 4-2. The drum is primarily designed to reduce airborne dust from cutting. The action of ten, high pressure nozzles, spraying into tubes which pass through the drum, induces air to flow across the picks to the face side and back through the tubes. This, it is expected, will ventilate the face side of the drum to remove methane. Also if, in spite of the ventilation and water jets onto the cutting picks, methane was to be ignited, the burning gas would be carried into the tubes along with the air. Here the flame would be cooled to extinguishment by the water sprays.

It is claimed that the sprays induce over $1 \text{ m}^3/\text{min}$ of air (40 cu.ft./min) to flow through each tube. For the system to operate, the shearer water pump must be changed for one that will produce a pressure of over 12 MPa (= 1750 psi) instead of the present 6.9 MPa (1000 psi); this will be done and trials will be conducted.

HD Extraction Type Shearer Drum (R.A.C)

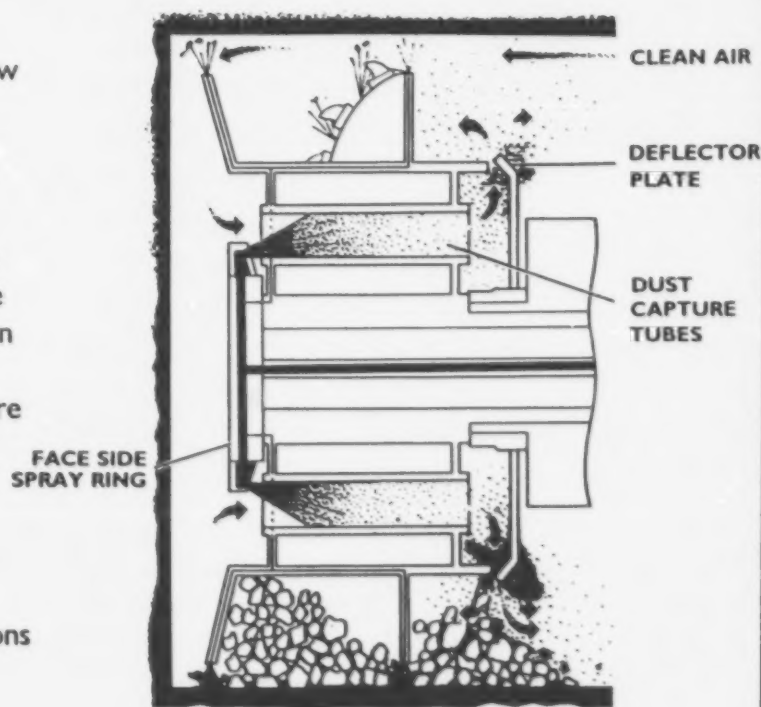
Our range of Anderson shearer cutting drums is specifically designed to suit the new generation of high powered, high output longwall shearers.

The standard range of shearer drums has now been supplemented by the extraction drum which can be applied to the complete range of Anderson shearers. The extraction drums are designed relative to the output shaft or epicyclic on the gearhead and ensure maximum haulage speed, high cutting tool penetration and long life.

This results in a larger product with a reduction in fines and dust make, which provides improved environmental conditions on the coalface.

The extraction drum is designed to reduce the amount of dust produced by cutting, by drawing dust laden air from the cutting zone through water powered 'dust capture' tubes built into the shell of the shearer drum (fig. 1 and fig. 2). High pressure water released from sprays induces an airflow from the face side of the drum and reduces the quantity of respirable dust. At the waste side of the drum a deflector plate, attached to the cowl arm (fig. 2) deflects the water spray, and a certain proportion of the cleaned air, back into the cutting zone.

The high level of air movement caused by the extraction drum also improves the working environment by diluting any methane gas present, so reducing the risk of frictional ignition.



Cross-Section Fig. 4.1

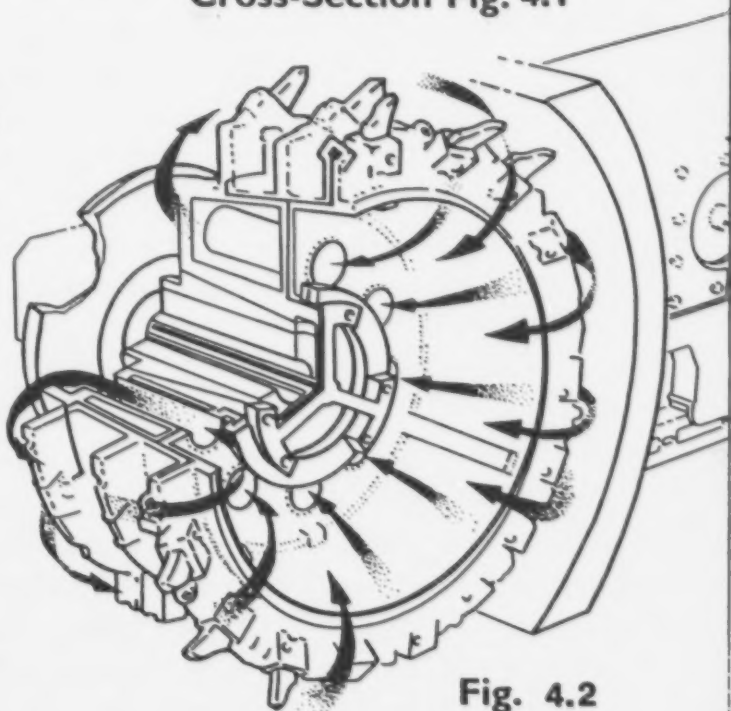


Fig. 4.2

Thirdly, improved ventilation and the introduction of methane drainage have reduced methane to levels below those at which ignitions have occurred in the past. This is further reinforced by continuous methane monitoring instruments with electric interlocks to cut off the power supply, stopping the shearer and other electrically powered machinery, when the methane reaches a pre-set level.

4.7 FIRES IN DEVELOPMENTS AND FACE LINES

4.7.1 Developments

In Lingan and Phalen "Main Deeps", development is done using boom type roadheading machines. The excavated roadway (5.6 m wide x 3.5 m high) is supported by steel arches or steel frames set at close intervals. All heading machines load directly onto belts; ventilation is by forcing fan and ducts.

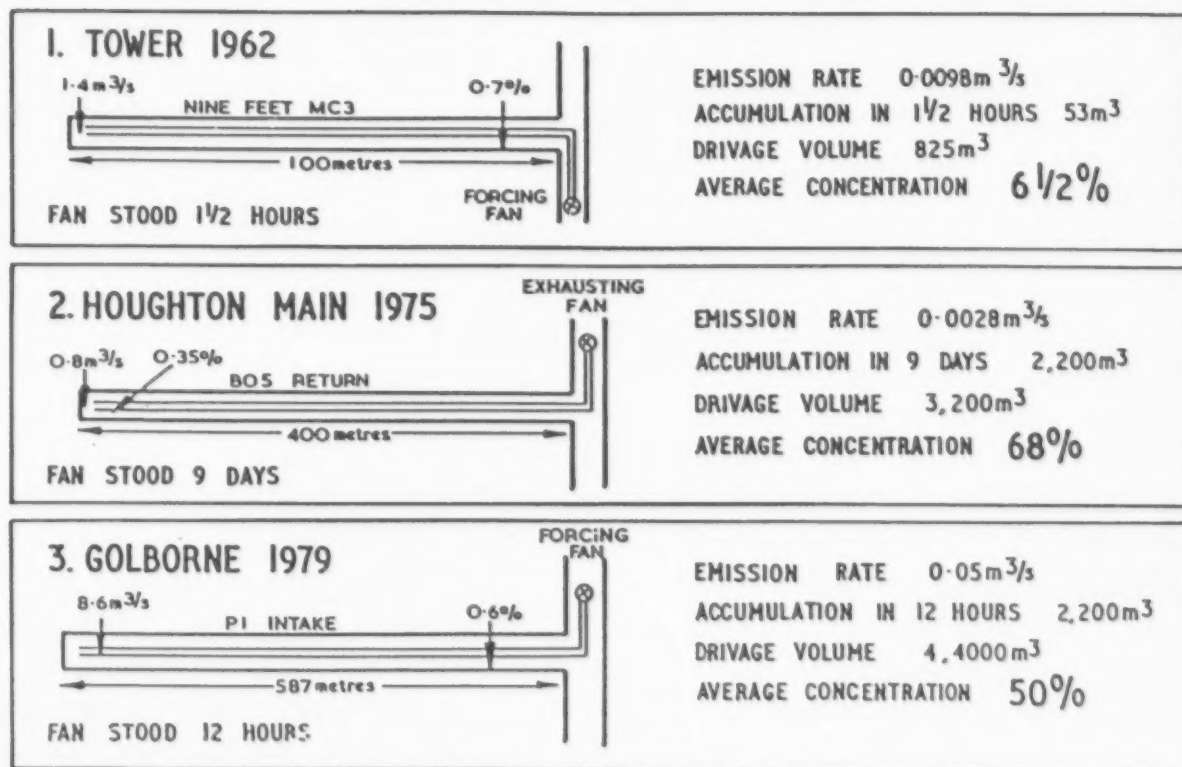
CBDC records showed that several methane ignitions had been caused by roadheader cutting picks striking floor rock of a high silica content. The adoption of water assisted cutting, in which machine mounted booster pumps are used, can help reduce this hazard. The pump boosts water pressure up to around 60 MPa and high pressure jets are directed onto the cutting edge of each pick. This cools the picks, helps prevent incendive sparking and, it is claimed, reduces airborne dust.

Incendive sparking, whether from picks or from electrical equipment, may ignite methane. Ventilation of development faces is therefore important and must be sufficient to remove methane and prevent accumulations of the gas, particularly in the face where cutting is being done. Under normal operating conditions the auxiliary ventilation systems in use are adequate. However, the headings are only mined for five days a week, work is

suspended over the week-ends to be started up again every week after a two day shut-down.

If the fans are left running to maintain ventilation, the heading and ventilation system should be examined during the shut down, probably at four hour intervals. If the fans are stopped, then the headings must be carefully examined before the ventilation is re-started and if gas has accumulated then the start-up of the ventilation must be done with great care. A pre-shift examination is routinely carried out before a re-commencement of work but it should also be done in time to allow a proper de-gassing of the heading to take place should de-gassing be necessary.

Experience in the U.K. has shown that ignitions of methane, in headings ventilated by auxiliary fans, is frequent enough to be deserving of special care and attention. The use of interlocks which cut off the power to forcing ventilation fans when gas is detected in the heading can present a very difficult de-gassing problem. De-gassing a heading can be more safely and easily controlled if the auxiliary ventilation uses exhausting fans with external motors and with a "De-gassing Device" installed between the fan and the ducts. The de-gassing device consists of a 3 m long metal duct which has large openings, fitted with sliding shutters, next to the fan; beyond the openings there is a butterfly valve set in the duct. By the combined adjustment of the sliding shutters and the valve, varying amounts of methane contaminated air can be drawn from the heading face, diluted by clean air entering via the sliding shutters and then exhausted from the fan while maintaining the methane concentration at safe levels.



Explosions in Drivages—Calculated Firedamp Concentrations

SEPTEMBER 1981

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SOURCE: F.B. TURTON, Mining Engineer, September 1981

FIGURE 4-3

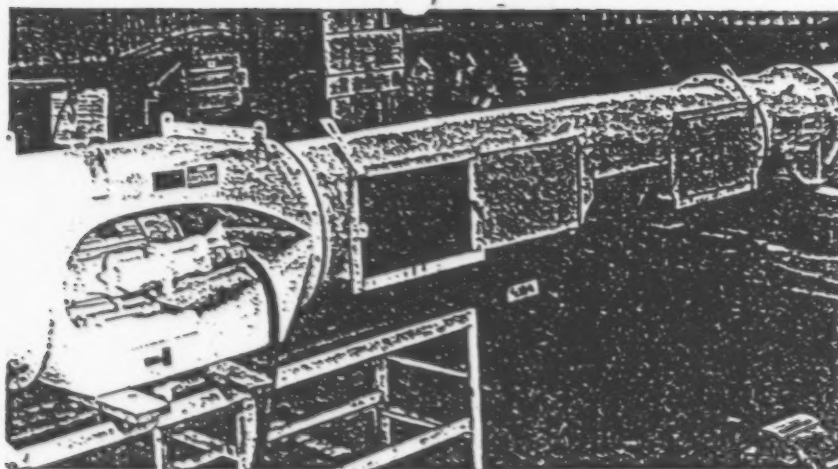


Fig. 1 De-gassing Device

Date of Test : 17th March 1980

Date of Test : 17th March 1981

TEST SETTING	COMBINED PITOT TUBE AND ANEMOMETER MEASUREMENTS				REMARKS
	Inlet		Outlet		
	ACTUAL VELOCITY m/s	QUANTITY m ³ /s	ACTUAL VELOCITY m/s	QUANTITY m ³ /s	
1	25.00	7.331	not measurable	not measurable	Dumper fully closed. Both sliding shutters fully open. Tests 1-12, taken progressively opening the dampers at each control point
2	24.76	7.236	0.44	0.128	
3	25.24	7.377	0.61	0.170	
4	25.00	7.307	0.79	0.231	
5	24.00	7.015	1.08	0.316	
6	25.40	7.424	1.34	0.392	
7	25.10	7.336	2.01	0.507	
8	24.25	7.088	3.54	1.035	
9	25.20	7.366	7.10	2.075	
10	24.77	7.240	12.58	3.676	
11	24.60	7.190	14.26	4.168	
12	25.90	7.570	18.70	5.466	
13	25.20	7.366	18.90	5.524	Dumper fully open Shutters fully open. Tests 13-24 taken progressively closing the shutters at 4 inch intervals until shutters fully closed
14	25.72	7.517	19.15	5.597	
15	25.20	7.366	19.18	5.606	
16	24.76	7.237	19.67	5.750	
17	24.00	7.249	20.00	5.866	
18	25.00	7.331	20.55	6.006	
19	24.10	7.219	21.06	6.156	
20	24.10	7.044	21.63	6.322	
21	24.63	7.161	22.10	6.460	
22	24.30	7.103	23.25	6.796	
23	24.30	7.103	23.59	6.895	
24	24.63	7.161	23.76	6.965	

Dumper fully open Both shutters fully closed

AREA OF DUCT = 24 ins. diameter = 3.14 sq. ft. = 0.2923m²

Table 4 Testing of De-gassing Device

-Selection of measurements made over 4 Hours-

TIME	FIREDAIMP % INBYE OF DEVICE	FIREDAIMP % INBYE OF FAN	DISTANCE TO GAS INTERFACE IN HEADING	VALVE SETTING	SHUTTERS' POSITION
09.25	0.20%	0.20%	18.5m	NIL (Closed)	Shutters Fully Open
09.30	10.00	0.60	—	1	Shutters Fully Open
10.20	27.00	0.80	28.5m	2	Shutters Fully Open
11.40	32.00	1.00	97.0m	4	Shutters Fully Open
12.00	30.00	0.90	121.0m	5	Shutters Fully Open
12.15	35.00	1.50	—	7	Shutters Fully Open
12.30	30.00	1.00	127.0m	5	Shutters Fully Open
13.30	15.00	0.60	175.0m	7	Shutters Fully Open
13.55	0.50	0.40	CLEAR	FULLY OPEN	FULLY CLOSED

FAN USED - ENGART 24"

FIREDAIMP REMOVED - 1400m³

Table 5 De-gassing of W14 Heading at Abernant Colliery, 10.1.81—Exhausting Mode

Examples of the accumulation of methane in headings are given in Figure 4-3. The results of de-gassing a heading using the de-gassing device are given in Figure 4-4. It is recommended that CBDC review their development heading shut-down and start-up procedures in order to:

- . be fully satisfied that a safe procedure has been authorized and is being carried out.
- . consider introducing the de-gassing device in conjunction with exhaust ventilation.

4.7.2 Facelines

Equipping new facelines and removing equipment from old facelines are not special fire risk areas however it is worth drawing attention to the following points.

- . New and old face lines may not be ventilated by the same air quantities as working faces and methane testing routines should not be relaxed.
- . When electrical equipment is being installed or removed, particular attention should be given to ensuring that:
 - . power is off before covers are removed and cable connections made and broken;
 - . that socket covers are put in place to prevent the entry of dirt and moisture into cable sockets;
 - . cables are properly handled and transported to avoid damage.

- . Mechanics should be careful not to:
 - leave spilled oil and part empty oil pails in and around the face;
 - discard oily rags and waste in and around the face.
- . Face lines should be well rock dusted.
- . Old face lines should be salvaged and sealed off as soon as practical.

4.8 MECHANICAL CAUSES OF FIRES

4.8.1 Friction

Probably the most common cause of fires from mechanical causes is frictional heat. This is usually the result of:

- . failed bearings;
- . misalignments causing rubbing;
- . bent and sprained parts causing rubbing; and
- . poor installation.

Good installation design, inspection repair and maintenance are the obvious remedies. Intermittent personal inspection can be supplemented by monitoring devices such as sensors for bearing temperature and vibration.

4.8.2 Hydraulic Fluids and Lubricants

Hydraulic fluids used in underground coal mines conform with the classifications of Canadian Explosives Atmospheres which uses the following International Codes for fire resistant fluids; these are:

- Category HFA - Oil in water emulsions, being about 95% water. They possess very little lubricating property.
- Category HFB - Water in oil emulsions, also known as invert or 60/40 emulsions. Water comprises 40% of these emulsions, with 60% comprising micronic or sub-micronic material in a two phase system. Lubrication properties are fair, but deterioration takes place at high temperatures.
- Category HFC - Water glycols which are true solutions comprising about 45% water. Additives render these solutions superior to invert solutions at the low temperature end of the scale, with similar limitations at the top end.
- Category HFD - Anhydrous synthetic fluids which derive their resistance to fire, not by water content, but by chemical composition or molecular structure.

The group is subdivided as follows:

- . HFD-R Phosphate Esters
- . HFD-S Chlorinated Hydrocarbons
- . HFD-T Mixtures of the above two substances
- . HFD-U Other compositions

The proper application of these fluids can be relied on to provide adequate fire protection.

The use of flammable grease and oil lubricants is unavoidable. The main precautions which should be pursued are:

- . Careful handling and storage of lubricant containers to avoid damage causing leaks;
- . The systematic removal of empty lubricant containers;
- . Not discarding empty grease cartridges and oily rags underground;
- . Preventing excessive lubrication leading to oil and grease drips.

4.8.3 Diesel Vehicles

Well maintained vehicles, especially exhaust flame traps, and well designed garaging and re-fuelling arrangements will minimize the risk of fire due to the use of diesel powered vehicles. In CBDC, diesel locomotives are widely used. The underground garages and fuelling arrangements are adequate and the concrete floors clean of oil and fuel spills; they are not regarded as a fire hazard.

5.0 DETECTION AND MONITORING

5.1 INTRODUCTION

Early detection of heating, smouldering and fire allows combat measures to be mounted before burning is beyond control. The earlier an attack on the fire begins the less are the risks to which workers are exposed.

Two types of fire detection which will be discussed are:

- . Direct personal detection
- . Indirect detection by instrumentation

5.2 DIRECT PERSONAL DETECTION

5.2.1 Introductory Remarks

A lot of fires in their early stages have been first detected by the human senses. Although instrumentation to detect fire is being increasingly used, the ability of underground personal to detect signs of heating at a very early stage AND TAKE IMMEDIATE ACTIONS must not be underestimated. The use of this ability can be improved by training. Training does not, of course, heighten the senses but it can teach a person to interpret what is sensed and what appropriate actions should be taken to minimize the dangers to himself, his fellows workers and the mine.

5.2.2 The Senses

Smell:

In a mine, the first sign of heat or smouldering is usually smell. Odours persist over long distances in mine roadways and the acrid smell of wood smoke, the bitumen-sulferous smell of smouldering coal, for example, can be detected long before smoke is visible and often long before the gasses emitted by burning can be detected by an instrument. To-date, no instrument has

been developed with the capacity of the human nose for detecting and differentiating between odours.

Sight:

Sight can detect the faintest of smoke hazes as well as wisps of smoke issuing from machinery or from behind doors or stoppings. Sight of course can detect the light from flame and incandescent material.

Touch:

Touch can be used to detect hot areas such as machine parts, bearings, roadway roofs, sides and floors. The examination of loose coal piles, for example, under conveyors and around return ends, should be done by touch. Heating of a coal pile may not be discernible by eye and only detected by handling the material.

5.2.3 Hand Held Instruments

Personal examinations in the mine rely on the senses assisted by portable instruments. These instruments include:

- . Combined methane/oxygen instruments which record the percentage of each gas in the atmosphere.
- . Hand held devices by which atmospheric samples are drawn through special glass tubes to create a discoloration of a chemical in the tube. The amount of discoloration indicates the concentration of gas present. Different types of tubes are used for different gasses.

- . Heat detectors using infra-red imaging which have been developed for underground coal mines are available in CBDC mines. Their use should be a standard aid for examination of conveyors, particularly during week-end shutdowns.

5.3 MONITORING

5.3.1 Introductory Remarks

Monitoring systems are usually part of a total "Monitoring and Control" system. The "nerve centre" of the system is housed in a "Central Control Room". At CBDC mines, the central control is manned round-the-clock, year round.

Monitoring is applied in two ways:

- . Environmental monitoring - of the mine environment; and
- . Equipment monitoring - which is often combined with remote control of the equipment.

5.3.2 Environmental Monitoring

There are two environmental monitoring systems available:

- . Tube bundle; and
- . Transducer sensors

Tube Bundle:

The tube bundle system consists of a bundle of very small diameter plastic tubes, passing from a surface site (usually adjacent to the control room) each tube terminating with its open end at different underground locations which are to be monitored. Mine atmosphere is drawn through the tubes into a surface gas chromatograph analyzer. The results of the analyses are recorded and diagnosed in a computer and a chart is printed

out. The system can be provided with audio visual alarms if readings exceed pre-set limits.

This system is not suitable over long distances and where there are large numbers of monitoring sites. It has now been largely superseded by transducer sensors.

Transducer Sensors:

Transducer sensors are employed at CBDC mines to monitor the underground environment. The system consists of three parts, the transducers or instruments, the outstation for converting the transducer signals into transmission signals, and the central station for collecting, controlling and analyzing the transmission signals.

Standard transducers and instruments for underground use are incorporated into the system and pass information to the outstation using a 0.4 to 2.0V instrumentation signal. The environmental monitoring outstation turns this signal into digital form suitable for transmission to the mine control room. The signal is interpreted by a micro-computer in the control room to give clear displays of the state of the mine ventilation at the various measurement points.

A number of transducer sensors are used at each monitoring station, usually to measure:

- . Ventilation air flow
- . Methane
- . Carbon monoxide
- . Oxygen (oxygen is not measured at CBDC)

Carbon monoxide and oxygen are the indicators for fire but methane and airflow are important during fire fighting activities. The sensors themselves have an on-site read out as well as visual alarms. The integrity of the sensors is regularly checked for accuracy.

The outstation is specially developed for mining environment monitoring. This unit has all its electronics mounted on a single large circuit board assembly, containing transmission circuits, digital interface circuits and analogue to digital converters. The design of the outstation is intrinsically safe. It is normally powered from any convenient lighting or auxiliary 110V supply through a flameproof 12V dc power supply unit, but a battery unit can also be provided to ensure that the outstation continues to operate in the event of power failure or shut-down.

The central station has a computer ASSEMBLY, and PRINTER.

A desk houses a visual display screen for environmental data display. A functional keyboard with capacitance switches is used, to control plant and for "configuring" the mine layout and data transmission details to build a system program to suit the particular application. This enables the following facilities to be determined using a simple question and answer routine through the keyboard:

- a) Adding or removing transducers from the system or re-defining parameters.
- b) Describing transmission outstation types and their relationship.

- c) Setting operating levels and limits, including calibrations for transducers/instruments.
- d) Setting system parameters such as date, time, shifts etc.
- e) Setting appropriate action messages for the operator following alarms and warnings of abnormal situations.

The system is "key protected" by a series of passwords which enable the management to determine the level of operator involvement.

The system is so constructed that any errors made in the process of configuring are immediately brought to attention and must be dealt with before proceeding any further.

With environmental monitoring schemes, once the system is in operation, changes are not frequently required.

At CBDC mines, monitoring and control is being standardized using the "transmittal" system for the "hardware" and "MINOS" as the basis for its "software".

The effectiveness of the system depends very much on the choice of sites for the sensors; the following are recommended:

- . At 1000 m intervals along main conveyor lines or just down-wind of each transfer point.
- . At booster fan locations and at the inlet to the main fan.
- . In development headings, in the ventilation return (which may be in the duct of an exhausting fan).
- . At the outbye end of main intakes and panel returns.

To put sensor stations at the return end of faces is desirable, however, this means constantly extending (or shortening) the system and this may jeopardize sensor integrity. A reasonable compromise would be to maintain sensor stations within 500 m of the face so that extensions and shortenings are required less frequently.

With constant collection and processing of environmental data the "normal" environmental conditions of the mine are well documented; but, more importantly, trend changes are also documented and can be produced in "hard copy". It is important to ensure that this data is being systematically reviewed and filed by an appointed person. This person must possess the technical competence to appreciate significant trends or changes and bring them to the attention of mine management.

5.3.3 Equipment Monitoring

Equipment monitoring is integrated with the "control" function and both are an extension of the transducer sensing system for environmental monitoring.

Equipment monitoring using transducer sensors enables the condition of operating equipment to be under constant surveillance by the control room operator. So far as fire detection is concerned, some of the important features that can be monitored are:

- . oil temperatures
- . bearing temperatures
- . vibration
- . conveyor belt slip
- . V-belt breakage

There are, of course, many other operating functions that can be and are, monitored and alarms or warnings registered at the control room must be followed up by personal visits to the site of the problem.

When heating and/or burning has been detected in a mine, the control room assumes a key role in the activities which follow. Ideally, the direction of emergency operations should be from a centre as close to the control room as possible.

The alertness and responses of control room operators are the vital link between remote monitoring and remedial action. It is important therefore that these operators are selected with care; clear guidelines and instructions should be established to help them make swift and appropriate decisions when data from the sensors indicates that something unusual is happening or when warnings and alarms are triggered in the control room.

Finally, it is essential that the integrity of the monitoring system is maintained and regular checks are carried out. Relying on an alarm system whose integrity can be questioned is worse than not having remote monitoring. The site of every alarm or warning signal should be visited and when ever warnings/ alarms are claimed to be caused by a system malfunction, the system's integrity must be checked, the malfunction corrected and confidence restored.

6.0 FIRE CONTAINMENT AND COMBAT

6.1 INTRODUCTORY REMARKS; ESSENTIAL COMPONENTS OF COMBUSTION

It is elementary, but worth repeating, that the three essentials to continued burning are:

- . Fuel - (i.e. coal, timber, oil)
- . Oxygen - (i.e. Air, normally containing 20% oxygen)
- . Heat - (generated by the fire itself to propagate burning but supplied from external sources to start a fire, for example, frictional heat, electrical faults.)

If one or more of these essential elements can be removed, then the fire MUST go out; this is the objective of all fire containment methods - to remove one or more of the essential elements.

In a coal mine it is difficult to remove fuel since it is everywhere, for example,

- Coal: - as solid coal sides of entries,
 - as loose coal allowed to accumulate along conveyors, around bunkers, in gobs.
- Timber: - as roadway support material, i.e. chocks,
 - in underground storage piles of chock pieces, covering boards etc;
- Oil: - standing in containers awaiting use,
 - leaking from damaged containers or equipment,
 - excessive lubrication of equipment.

- Explosives: - left behind in carrying canisters when evacuating the fire area,
- irresponsibly abandoned or 'lost' in the mine before the fire.

6.2 IMPORTANCE OF IMMEDIATE ACTION

6.2.1 Role of People On-the-Spot

All minor fires, suspected fires and events which could cause fire, require IMMEDIATE ACTION BY THE PEOPLE ON THE SPOT. All minor and suspected fires have the potential to become DISASTERS. The sooner they are dealt with, the simpler their extinguishment and the less the risks involved. Every fire underground causes some loss (even if it is only loss of time) and some danger. Damage, losses and danger escalate rapidly if the fire is not dealt with quickly. Multi-fatalities can result from smoke and fumes produced by a simple, localized, burning and carried into working places by the ventilating current.

Successful, direct action, by people on the spot depends on the following:

- . Full appreciation of the dangers of underground fires.
- . Determination to deal with the situation quickly no matter how minor it may appear to be.
- . Knowledge of how to use extinguishing equipment and materials to hand.
- . Fire fighting equipment being readily available and in working order.
- . Fire hydrant water supply at adequate pressures and volumes.
- . Ability of people on the spot to collaborate.

The above items should be included in basic fire fighting training.

6.2.2 EQUIPMENT AND MATERIALS FOR IMMEDIATE ACTION

(a) Hand Held Extinguishers

Availability

Extinguishers are required at all sites where there is a foreseeable possibility of fire. This includes:

- . Electrical units such as transformers, switches, controllers, motors, etc.
- . Drive units for rope haulages and Conveyors
- . Coal/rock cutting and loading equipment
- . Fans
- . Oil and fuel storage sites
- . Locomotive garages and repair shops
- . Bunkers

Extinguishers are not usually required at the return pulleys of conveyors however, experience has shown that this is a fire risk area where extinguishers should be readily available.

Adequacy

Dry chemicals type extinguishers, ranging from 5 kg to 10 kg powder capacity, are usually preferred though carbon dioxide is another commonly used extinguishing agent. A maintenance program ensures that extinguishers are operational and provided in sufficient number at each location to meet Regulatory and Company standards. In coal mines, Regulations usually require that the extinguisher has no exposed light metal alloy parts.

(b) Water Supply, Hydrants and Hoses

Water Supply

Water supply systems must be designed to ensure an adequate water reserve capacity and be able to operate safely at the required pressures. The CBDC mines have a minimum mine site capacity of approximately 100m³ (22,000 gal.) with a back-up of approximately 500m³ (110,000 gal.) available within one hour.

Normally, the same pipe lines are used to supply operating water needs (i.e. dust suppression) as well as fire fighting needs. When pressure requirements exceed 3.45 MPa (500 psi) it has been recommended that fire fighting pipe lines are installed as a second, duplicate line; (G.A. Haslett; The Management and Use of Water in Underground Coal Mines; Feb. 1987, CANMET Division Report ERP/CRL 87-6 (INT)).

Hydrants

Hydrants should be clearly marked and located at intervals along the water pipes lines, regulations require not more than 150 m (500 ft) apart. They should also be provided at (or close to) production walls and where machinery is operated. CBDC operating standards require a minimum flow pressure at the hydrant of 0.7 MPa (100 psi) and a delivery of 6.2 l/s (81.8 gal/min).

Hoses

Hoses should be made of rot-proof material and have a diameter not less than 38mm (1 1/2 ins.). They should be supported off the ground in a manner which allows them to be quickly pulled free without twisting. Each set of hoses should be provided with a nozzle capable of delivering water in either a spray or a jet.

A supply of hoses is provided at each fire hydrant. There should be enough hoses to reach to the next hydrant (since in most cases a fire will have to be attacked from its intake side and it might be at, or close to, the next hydrant).

Rock Dust

Rock dust is generally available in most parts of a coal mine, supplied in fire resistant, easily handled, paper bags.

Rock dust can be used effectively for a number of purposes including:

- . Smothering burning coal discovered in floor spillage, conveyor drives and return pulleys etc.
- . Retarding the spreading of fire and possible ignition of coal dust by liberal application in the vicinity of a fire.
- . Smothering and isolating hot/smoldering material being transported away from a fire in mine cars. (Usually wetted down with water).
- . Applying a covering of rock dust over spilled oil to minimize the danger of ignition.

Rock dust can be applied as a supplement to dry-chemical extinguishers when attacking small fires - it will never worsen a situation. However, it may not be possible to approach close enough to open fire to permit rock dust to be manually applied.

In CBDC mines, rock dust dumps are maintained at numerous locations around the mine.

(c) CBDC Standards

The "Fire Loss Control - Unit Standards Reference Manual" of CBDC, deals with water supply and fire protection for all underground operations in considerable detail in Element No. 21. The table of contents of this element is given in Table 6.1. This manual will be referred to in subsequent sections of this report as "The Fire Loss Control Manual".

It sets out the standards of fire control which CBDC wishes to see implemented and details a system of inspecting and evaluating compliance with the standards. The manual acknowledges the necessity of training and describes training course content for using fire fighting equipment.

(d) Training for Immediate Action

For fire combat to be effective in the vital, early, stages, training is of paramount importance. This means training of the workers and supervisors on the job. In addition to the items listed in 6.2.1, the training should include:

- . recognition of the signs of heating and burning;
- . locating the seat of the fire and its cause;
- . speed and teamwork drills
- . the use of fire fighting appliances;
- . the importance of communication and the procedures for warning other sections of the mine;
- . techniques for attacking fires
- . safety measures

TABLE 6.1

CBDC FIRE LOSS CONTROL MANUAL - ELEMENT 21TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>
1	FIRE LOSS CONTROL EVALUATION.
2	WATER SUPPLY AND FIRE PROTECTION FOR ALL UNDERGROUND OPERATIONS.
2 SUBSECTION	A MINE FIRE FIGHTING CAR.
	B UNDERGROUND FIRE EQUIPMENT BOXES.
	C FIRE EQUIPMENT PLANS FOR ALL COLLIERIES.
	D STANDARD - FIRE EXTINGUISHER LOCATION, QUANTITY AND TYPE REQUIRED IN UNDERGROUND OPERATIONS.
	E REQUIREMENTS FOR REGULAR MEASUREMENT OF FLOW FROM CONFLOW HYDRANTS.
	F FIRE EQUIPMENT RECORD BOOK FOR ALL COLLIERIES.
	G AUTOMATIC WATER CURTAIN SYSTEMS
3	PERMIT FOR CUTTING AND WELDING (SURFACE OPERATIONS).
4	FIRE PROTECTION WATER SUPPLIES FOR SURFACE OPERATIONS.
5	RECHARGE PROCEDURES AND MAINTENANCE FOR LTA-101-30 FIRE SUPPRESSION SYSTEMS.
6	STANDARD - FIRE EXTINGUISHER INSTALLATION, INSPECTION AND MAINTENANCE SURFACE OPERATIONS.
7	CONTRACTOR SAFETY/LOSS CONTROL FIRE PREVENTION AND FIRE PROTECTION.
8	AIR PAG STOPPINGS FOR EMERGENCY USE.
9	INSPECTION AND TESTING - FIRE ALARM SYSTEMS
10	WATER BARRIERS/STONEDUST BARRIERS.
11	PERMITS FOR SHUT DOWN OF WATER SUPPLIES REQUIRED FOR FIRE PROTECTION.
12	FIRE EQUIPMENT LOG BOOK FOR ALL SURFACE OPERATIONS.
28	FIRE PROTECTION - CENTRAL WAREHOUSE INVENTORY
30	CRITERIA FOR AWARDS
31	FIRE LOSS CONTROL LIBRARY.

Basic fire-fighting training should be given to all employees. Drills and practices involving groups who normally work together or in the same vicinity, are a good way to structure practice programmes. Supervisors should receive extra training to enhance their ability to:

- . direct immediate fire combat activities;
- . communicate and give clear accounts of the situation to Central Control and Management;
- . obtain reinforcements;
- . organize and lead a speedy evacuation;

6.3 FOLLOW-UP ACTION

6.3.1 Emergency Plan

As soon as the incident has been reported to surface control, the senior official at the mine should be kept informed of developments. The advice of the person who is directing the fire fighting will be invaluable as the Senior Official in charge at the mine will have to decide very quickly:

- . If and when the Colliery Emergency plan will be put into effect ;
- . What sections of the mine should be evacuated immediately and by what routes;
- . What re-inforcements must be mobilized; and
- . What might be safely done to retard the progress of fire and protect life and property.

He must designate a mine official to compile a list of the persons still in the mine and try to verify their location.

6.3.2 The Role of Supervisors

During an underground fire, supervisors can play a vital role. The greater their knowledge of mine fire behaviour and underground fire conditions, the better is their ability to direct people to safety and take steps to minimise fire damage.

Supervisors must ensure that self rescuers are distributed and, when required, are correctly worn. It is the supervisor who will:

- . direct the evacuation of his section of the mine;
- . make progress and mine condition reports to surface control;
- . prevent reckless action and attempt to avoid the onset of panic;
- . be prepared to lead evacuating personnel through zones of dense smoke;
- . ensure that requirements of the Emergency plan are complied with; and
- . organize the implementation of any instructions given by the Central Emergency Control.

6.3.3 Provision of Back-up Equipment

This consists of collecting additional tools and equipment which can be quickly brought to the scene of a fire enabling the initial efforts to extinguish the fire to be increased and sustained. The CBDC Fire Loss Control Manual lists this equipment as:

- . A fire fighting car, rail mounted, pre-loaded with fire fighting equipment that can be moved to most underground locations. The car is held at the surface of an intake deep ready to be lowered into the mines. The car carries a foam generator and foaming chemicals.
- . A Fire Equipment Box is provided at each mine's first-aid (medic) cabin located near the bottom of the main slopes. The boxes store a supply of tools and equipment necessary to increase the capability of applying water to a fire.

6.4 PRE-PREPARATION OF PREVENTIVE MEASURES

6.4.1 Introductory Remarks

Pre-Preparations for containing fires and/or explosions are carried out following a previously devised plan or strategy. High fire risk areas are identified and fire containment methods appropriate for different sections, entries or equipment of the mine are proposed.

Since speed of response is of the utmost importance to reduce damage and minimise personal risk when attacking fire, anything that can be done by way of preparation at reasonable cost should be seriously considered. This is an area where cost/benefits or perhaps more aptly, cost/risk should be carefully addressed.

Pre-Preparation efforts concentrate on:

- . Installation of automatic fire attack systems such as,
 - Automatic Extinguishers
 - Water Curtains
 - Barriers, passive and triggered

. Preparation of fire control sites such as:

- Pre-prepared fire seal sites
- Fire proof doors and stoppings
- Fire breaks or fire barriers

6.4.2 Installation of Automatic Fire Attack Systems

These devices fall into two categories, Automatic Extinguishers and Barriers.

(a) Automatic Extinguishers

Automatic extinguishers are installed at the sites of important/expensive equipment where there is a foreseeable fire risk. They are triggered by a heat sensitive device which causes dry-chemical or foam to be directed over selected parts of the installed machinery or equipment to smother the fire. Dry chemical is the preferred extinguishing medium in the presence of electrical parts. The system used by CBDC consists of dry chemical powder, forced through hoses by pressurized nitrogen from a battery of cylinders, and discharged from nozzles suspended over the machinery. This system has been installed at large, main conveyor drive units situated at intervals down the main conveyor deeps.

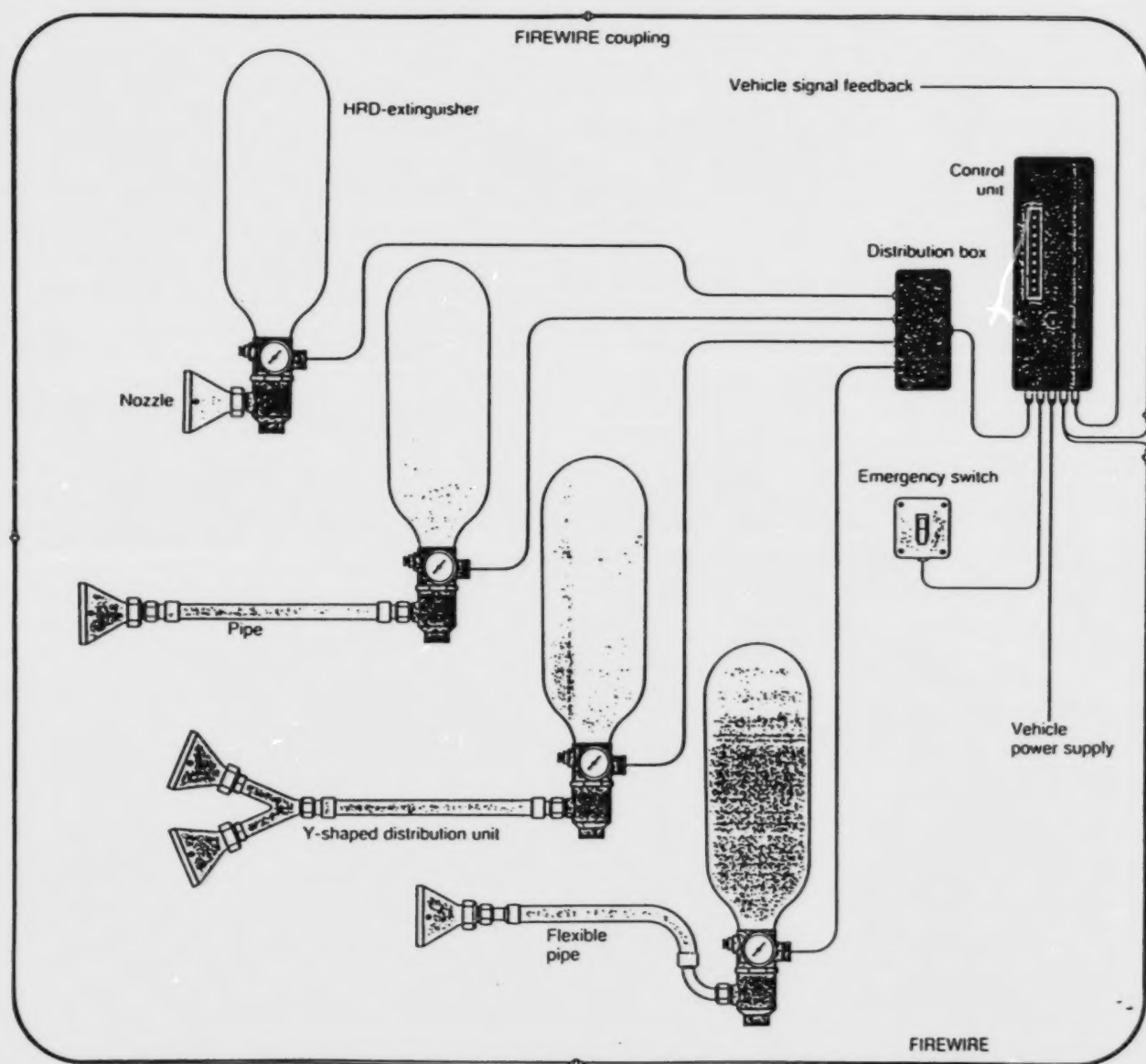
Figures 6.1 and 6.2 show automatic dry chemicals extinguishing systems for use on stationary and mobile equipment respectively.

(b) Water Curtains (or Water Drenchers)

The application of water curtains is similar to that of the automatic extinguisher except that the extinguishant is water. Sensors detect heat or smoke etc. and trigger a valve, or fusible links fail in the presence of heat, allowing a weight

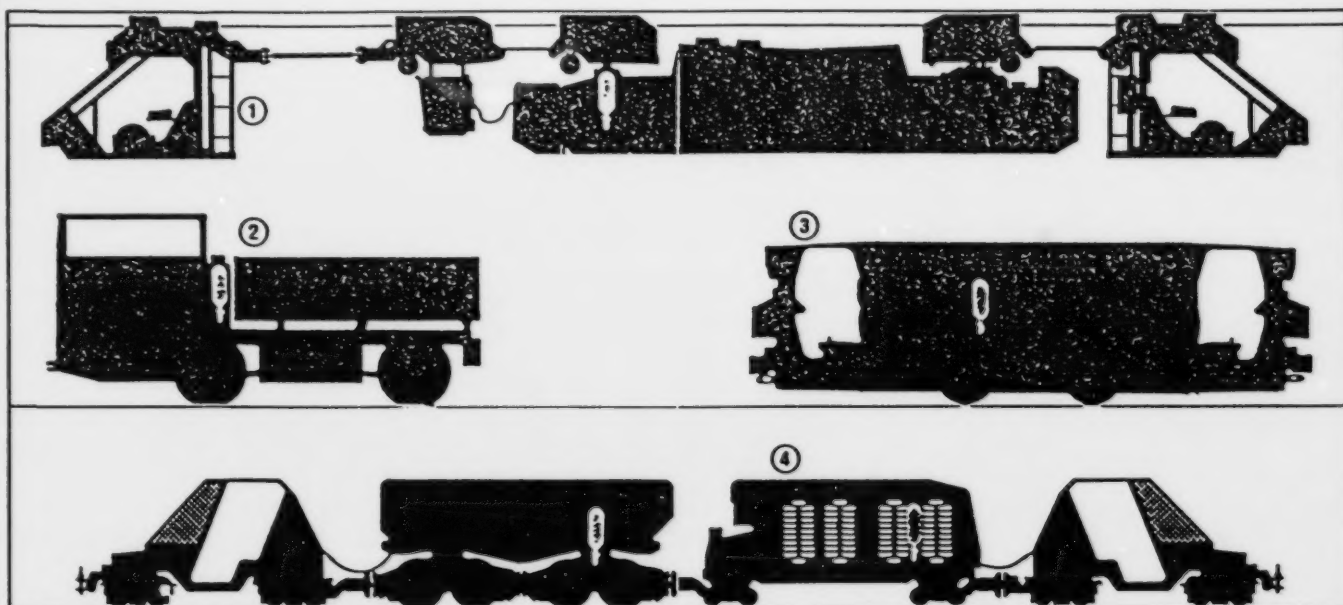
FIGURE 6-1

AUTOMATIC EXTINGUISHING SYSTEM FOR STATIONARY EQUIPMENT



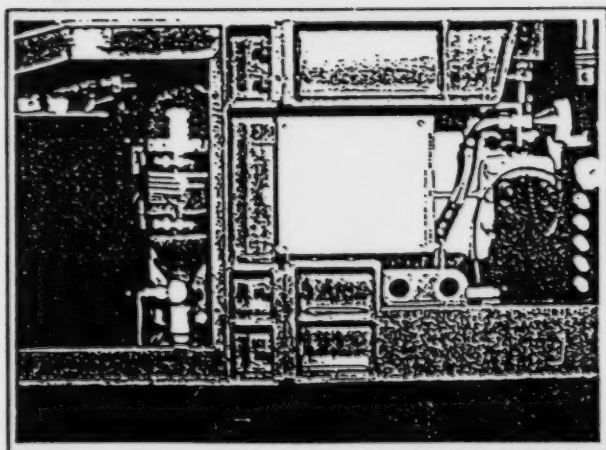
Complete DEUGRA
Fire Extinguishing System
in maximum extension.

AUTOMATIC EXTINGUISHING SYSTEM FOR MOBILE EQUIPMENT



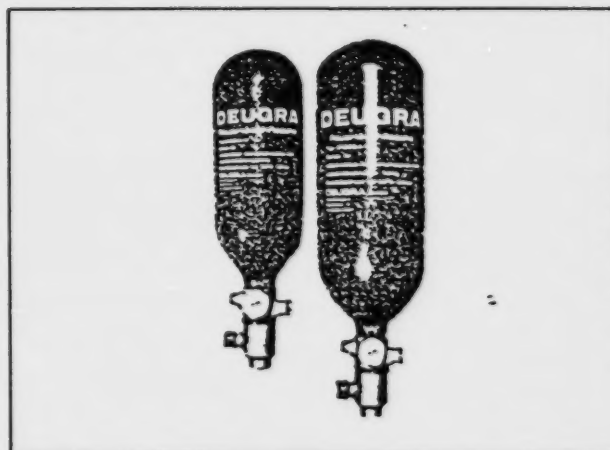
Applications in diesel-powered
underground mining vehicles:

- ① Scharf monorail
- ② GHH trackless vehicle
- ③ Ruhrthaler locomotive
- ④ Klöckner-Becorit locomotive



Left:
DEUGRA Fire Extinguishing System installed
in a GHH trackless vehicle.

Above:
DEUGRA Fire Extinguishing System installed
in a Scharf monorail.



FIREWIRE is a firewarning system, which is installed in the engine bay in such a way that a fast fire detection is ensured. If the temperature rises the FIREWIRE changes its impedance and by means of a signal to the control unit releases the extinguishant. The signal from the FIREWIRE is evaluated and analyzed by the control unit, to differentiate between fault and fire.

activated lever to open a valve. This admits water to a series of manifold pipes, each having an array of sprays. Water curtains may be used in fire risk areas but the application of water over electrical equipment or oil may create problems. When the curtains are activated, a length of roadway, about 20 m long, is drenched with large volumes of sprayed water.

(c) Barriers

Barriers consist of sections of entry in which either shelves of rockdust are used or water containers are supported or suspended. In both cases, the shelves or containers conform to a particular design which specifies spacing and quantities of rock-dust (or water) to be used. Barriers of this type are intended to arrest the passage of an explosion of methane or coal dust. They are considered here as automatic because the shock wave, which precedes the flame of the explosion, upsets the structures of the barrier filling the air with rock dust or water particles.

When the flame reaches the zone saturated with rock dust (or water) it is cooled and deprived of the fuel concentration needed to propagate the flame. The flame is consequently extinguished if the barrier has been effective.

The process described above is that of a "Passive Barrier".

There are also "Triggered Barriers" which consist of:

- . a sensing or detecting unit;
- . a dispenser; and
- . a suppressant.

The explosion is detected by a sensor sensitive to one or more characteristics of an explosion such as temperature, infra-red, ultraviolet, air velocity (i.e. blast) or air pressure (i.e. shock wave).

The sensor relays an electronic signal to the disperser where electrical or mechanical devices, or an initiated detonating cord, triggers the release of suppressants which are hurled into the path of the on-coming explosion to extinguish the flame and arrest its progress. Table 6.2 summarizes some of the triggered barrier systems used throughout the world.

(Ref: "Passive and Triggered Barrier Systems for Canadian Underground Coal Mining Conditions", Brian Mountford and Assoc. CANMET REPORT, March 1983)

6.4.3 Preparation of Fire Control Sites

(a) Pre-Prepared Fire-Seal Sites

Pre-selected sites for fire-seals, where initial site preparation work has already been done, save valuable time and risk to personnel can be reduced. The excavation of the floor, roof and sides to receive the walls of the stopping is a great time saver. In some locations the walls may be already partially built so that even more time can be saved. This is done in most production panels in CBDC mines. In addition, sufficient construction materials can be stored nearby to enable seal building work to be started immediately without waiting for the first train of supplies to arrive.

TABLE 6.2 - TRIGGERED BARRIERS

SUMMARY OF DISPERSER INFORMATION

After Mountford & Ass.					
DISPERSER	CONSTRUCTION MATERIAL	ENERGY SOURCE	SUPPRESSANT	CAPACITY	BARRIER SYSTEM
Water Trough	PVC	Detonating Cord	Water	80 L	System Tremonia - German
Water Trough	Polystyrene	Unknown	Water	30 or 50 L	Romanian
Water Trough	Flexitrough	Mechanical	Water		Japanese
Water Trough	Triangular Metal	Detonating Cord	K_2CO_3 + Fine Limestone Dust	25 L	CERCHAR - France
Water Trough	Triangular Steel	Detonating Cord	Water	68 kg	SMRE
Cylinder	Steel	Carbon Dioxide	$KH CO_3$ or Water		CARDOX-U.S.A. High Pressure
Cylinder	Steel	Compressed Nitrogen	Ammonium Di-hydrogen Phosphate		Low Pressure FENWALL-U.S.A.
Cylinder	Steel	120 ATM Nitrogen Gas	Water	4 or 8 kg	Polish
Cylinder	Steel	Compressed Nitrogen	Ammonium Phosphate Phosphate		"BVS" System - German
Cylinder	Steel; Gun-shaped	Compressed Nitrogen	Water		SMRE Mark II England
Cylinder	Steel	Rocket Powered	Water		SMRE - England
Foam Cylinder	Cylinder Enclosed in PVC sheet	Detonating Cord	Water		INIEX - Belgian
					Operational since 1974 in Germany
					Automatic Tripping System
					Researched and tested but not employed
					Too dangerous if personnel present
					Not yet adopted for use in Polish coal mine cyl. of Austrian manuf. Can only be used where no personnel work
					In use in some coal mines
					Rocket motor generates gas pressure-not in use

Pre-selected fire-seal sites must allow enough space to accommodate an explosion-proof construction and possible extensions. The selected, fire-seal sites should be marked on rescue and firefighting plans. Selection of the sites should consider:

- . Strategic Location; taking account of,
 - proximity of other workings.
 - cross-section of the opening (small and regular is best).
 - competency of strata-not broken, no fissures in roof and floor.
 - accessibility by materials transport systems.
 - close to good ventilation circuit, (20 m is about right).
 - free of major structures (e.g. conveyors) if possible.
- . Size of the Sealed-off Area; this means not only the length of roadways to be closed off but also the volume that will be enclosed by the seals. In principle, smaller is better than bigger because smaller volumes more rapidly become extinctive. However, there are other important considerations,
 - the seal should be substantially completed without the fire coming within 150 m of the seal building crew.
 - the volume being sealed may become an explosive mixture before it becomes extinctive;

Pre-prepared fire-seals will be utilized in the second stage of fire-containment, i.e. after immediate attacks on open-fire have failed. Where spontaneous heating is a problem, the heatings are usually detected at an early stage of development and speed is not so vital. Also, the locations of heatings are difficult to predict and it is not usually possible to pre-select suitable fire-seal sites.

The design of mine layouts should provide zones where discrete sections of the mine might be sealed off and sites for fire-seals pre-prepared. Pre-preparing a site can be done more effectively and at less cost than when it has to be done quickly in an emergency, probably at two or even three times the basic labour rates. When fire-seal sites are pre-prepared they should

be done well and according to a specified standard. If not, they are a waste of effort and give a false sense of security.

(b) Fire Proof Doors and Stoppings

Fire Doors

These are doors of non-combustible material (usually steel doors in a concrete wall). Their purpose is to resist the progress of a fire. They are usually installed in roadways which connect different mines or important sections or entries in the same mine, (i.e. main intakes and returns).

Fire doors, to be effective must be massive; embody high standards of construction to withstand heat and distortion; and be installed where the tunnel is in rock. A simple steel plate door in a brick or 25 cm concrete wall cannot be considered fire proof though it may be effective in holding back smoke.

Where these doors are normally open for ventilation, the problem arises as to how the door will be quickly closed in an emergency.

It is unrealistic to depend on these doors to prevent the spread of fire indefinitely however they would make a valuable contribution by slowing the progress of a fire, perhaps for many hours, depending how well they are constructed.

A "fire proof" door constructed in a roadway with coal ribs would be very unreliable. To have even a significant retarding effect, its massive, concrete walls would have to be set back into solid coal ribs, floor and carbonaceous roof rock, for at least 3 m.

Stoppings

The comments about fire doors apply to fire stoppings. They must be massive (made of concrete) and ideally sited in zones of non-carbonaceous rock. If this isn't possible they must be embedded into the roof floor and sides by at least 3 m. If this is not done, a fire can burn the coal around the perimeter of the stopping separating intake and return very quickly, possibly within minutes. As a guide, a fire stopping should be constructed like a fire-seal; their purposes are the same. None of the stoppings between main intakes and returns in the CBDC mines are constructed in this manner so must be regarded as fire resistant smoke stoppings but not FIRE stoppings.

(c) Fire Breaks or Fire Barriers

Where timber, and other combustible material is used as part of roadway support, these materials can be sprayed or treated to render them fire resistant. It is questionable whether this process is sufficiently effective to justify the cost. The use of fire breaks or fire barriers can be considered as either a supplement to fire resistant timber support material or as an alternative to rendering the total length of a roadway "fire resistant".

A fire break is a length of roadway in which combustible material is totally absent so that the spread of fire is halted. Ideally, a fire break would be located in a level section of tunnel driven in rock. Fire breaks in roadways driven in coal are smooth lined with special, heat resistant, lining. All combustible material is removed, i.e. conveyor belting, hoses, cables, etc. Where communication or power cables **MUST** pass through they are buried deep in the floor. This would also apply to pipes in which combustible joint gaskets are used. The fire-break zone should be liberally spread with rock dust. Barriers of this type might be considered at the bottom of all main return deeps. Since temperatures in excess of the ignition temperature of coal and wood (and similar materials) can be carried down-stream of a fire for considerable distances, the fire-break length should be **AT LEAST 200 m.** There is also the danger that hot ash and burning fragments can be carried through the fire break by the air current.

The effectiveness of fire-breaks in underground mine fires is not proven and further investigation is needed. For a fire-break to be fully effective and reliable it might have to be combined with an additional feature like the water curtain.

6.5 FIRE FIGHTING - DIRECT ATTACK (OPEN FIRES)

6.5.1 Opening Remarks

This section of the Report addresses the combat of "Open Fires". This means fires which occur in active mine roadways, production faces and places contiguous to them such as abandoned mine roadways and those areas of gob immediately adjacent to working faces. The fire fighting methods applied to underground spontaneous heating of coal is discussed in Section 6.6. Literature is available which deals with fighting underground mine fires in considerable detail; some of these are listed in

the body of the report and also in the Bibliography at the end.

6.5.2 Importance of Speed

The time available to make an effective direct attack on an open fire is very short. Speed is essential because once the fire has taken hold, putting it out is usually very unpleasant and dangerous. Once the fire has become established, if its progress is not quickly arrested, it will spread around the perimeter of roadway and start to progress along the roadway. It may spread into inaccessible areas such as gobs and old workings where it cannot be attacked. When this happens continued direct attack is impossible and there is great danger of methane ignitions and explosions.

6.5.3 Use of Water to Remove Heat

The removal of heat is the main objective of direct attack fire-fighting. The application of water, using hoses and nozzles, must be started as soon as possible.

A large amount of heat is taken from the fire as the temperature of the water is raised to boiling point, (approx. 418 KJ/Kg of water) and more than five times this amount on being converted to steam (approx. 2.26 MJ/Kg). This is why water applied as a mist or spray is more effective than as a jet. Spray droplets are quickly converted to steam; a jet forms pools or rivulets which allows the water to drain away from the fire before it has absorbed the heat.

Hosing water on an open fire must be done from the INTAKE SIDE and this puts a limit on how long hosing can continue. The fire will travel down-wind leaving behind a burned out, dangerous roadway. It will be unsafe due to roof falls, where wooden support has been burned away. Steel supports will have been weakened and distorted by the heat. The roof strata too, will have been cracked and split by the heat and dangerously weakened when it is wetted down by cold water. Fire fighters clearly cannot advance more than two or three metres into these conditions and their ability to hose down the fire is limited by the amount of water mist carried onto the fire by the air current.

6.5.4 Fire Fighting With Foam

Foam Generators of the type provided by CBDC on the Fire Fighting Cars can produce three types of foam:

- . High expansion
- . Medium expansion
- . Low expansion

The foam generators operate from a mine water supply at a maximum pressure of 690 KPa (100 psi). The water flow passes through an eductor which draws a foaming agent from a 500 dm³ (110 gal.) supply tank. The agent mixes with the water and both flow through a nozzle which admits air to the liquid and generates foam. Different combinations of eductor and nozzle are used to produce different foam expansions - See Table 6.3 Capacities of Fire Car Foam Generators.

TABLE 6.3

CAPACITIES OF FIRE CAR FOAM GENERATORS

MINE WATER SUPPLY		FOAM EXPANSION		
690 KPa (100 psi)		HIGH	MED.	
LOW				
Eductor used.	Litre/min	430	365	270
	G.P.M.	95	80	60
Foaming Agent Concentration		1.5%	3.0%	5.0%
Expansion - liquid to foam		1:460	1:20	1:5
Volume of Foam Produced -				
	m ³	200	7	1.4
	Cu.ft.	7,060	260	50
Duration of foam Production				
	minutes	77	46	37

The low expansion foam is very suitable for combatting burning oils, oil fuel and volatile liquids. However, the time required to get a foam generator to the fire and into operation seriously limits its effective use.

The high expansion foam is generated at a rate at which it quickly fills a roadway or motor room. Its application against mine fires is described in "The Michael Colliery Fire" - The Mining Engineer November 1969, and "Practical Aspects of the Foam Plug Method of Fighting Large Mine Fires" - SMRE Report No. 163, February 1959. Experience has been that, although a slight air flow in a roadway is sufficient to move a foam plug, it often blows a clear path across the top of the plug and the body of foam doesn't move.

Some fire fighting authorities hold the view that, because of the air trapped in the bubbles, high expansion foams do not smother the fire and there have been cases where a fire has continued to burn while submerged in foam. Most engineers recognize that, in mines, the effective use of foam is limited to confined spaces like motor rooms.

6.5.5 Smoke and Fire Fighting Conditions

(a) Smoke

Smoke is one of the main difficulties for fire-fighters underground. In its mildest form it appears as a light haze which is typical of spontaneous heatings. Open fire produces large volumes of smoke - often at a high temperature. The nature of the smoke depends on the materials fueling the fire:

- . Wood - produces a greyish acrid smoke;
- . Oils, Rubber and Plastic - produce very dense black oily toxic smoke; and
- . Coal - produces dense black, sooty, tarry smoke.

As a fire progresses and more timber, coal, oils and plastics are consumed, the smoke colour darkens and the density increases until it is impossible to see on the downwind side of the fire.

The burning of coal, oils, plastics and rubber produces a range of gases and vapours which include:

- . ethane, propane, ethylene, benzene and toluene;
- . ammonia and oxides of nitrogen;
- . hydrogen chloride and hydrogen cyanide; and
- . phosgene.

These gases are responsible for the distinctive smells of smoke and fire, and can be irritating and hazardous to health. The sooty, oily, tarry deposits on the exposed skin of fire-fighters are very difficult to remove and suitable cleaning solvents should be available at the mine in copious quantities. The smoke will contaminate all the mine roadways down wind - that is on the return side - of the fire. It may even be discharged from the main fan or mine exit and still be dense even after being diluted by uncontaminated air circuits.

The atmosphere in some sections of the mine downwind of the fire may be irrespirable due to oxygen deficiency, smoke and toxic products of combustion. It must be an early objective in a fire incident to arrange for the examination of the entire return airway systems, starting from the surface, to determine the danger zones. These zones should be marked by notice boards indicating where breathing apparatus is required.

This examination must be cautiously carried out by people knowledgeable in recovery work and provided with self contained respirators and testing instruments.

(b) Smoke Control

When approaching a fire from the intake side, a water curtain across the roadway section, formed by using spray nozzles, has been found effective in holding back smoke and dust (which the water washes to the ground) without blocking the ventilation flow.

(c) Smoke Layering

The thermal effects of a fire often cause the smoke to layer at the roof of the airway near the fire site; two phenomena become apparent. Firstly, the demarcation between cool fresh air in the lower part of the roadway and the hot smoke in the upper part, is very distinct; this is partly due to the poor thermal conductivity of air. The thickness of the smoke layer, relative to that of the air layer depends on the heat intensity of the fire and the strength of the fresh air flow. In steady air flow conditions, smoke layering may extend for several hundred metres down wind of the fire until turbulence produces a homogeneous mixture at a warm even temperature.

It is not uncommon for a layer of smoke at roof level to move against the ventilation flow. Examples of this are:

- . Whitehaven Colliery (UK) 1910. Smoke backed-up 340m against an air velocity of 1.6 m/s; and
- . A small conveyor fire, where a 60 cm thick smoke layer backed-up 90 m against an air velocity of 0.25 m/s.

The results of tests in a 2.4 m (8ft) high, horizontal roadway, show smoke back-up against air velocities of 0.5 m/s (100ft/min) and 0.9 m/s (170ft/min) for distances of over 25m. This is illustrated in Fig. 6.3 showing also the temperature of the smoke at roof level.

Smoke layering can make it very difficult to approach the seat of a fire from the intake side. However, experience has shown that a hurdle sheet (of brattice or other suitable material) can be used to prevent a layer from forming or to dissipate a layer already formed. Fire fighting techniques have been developed enabling fire fighters, using a portable hurdle sheet (or sail) to advance in fresh air until they are close to the seat of the fire.

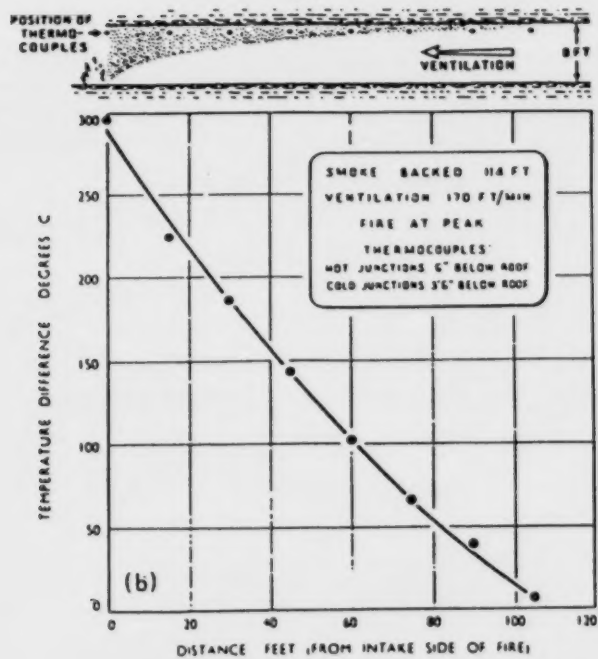
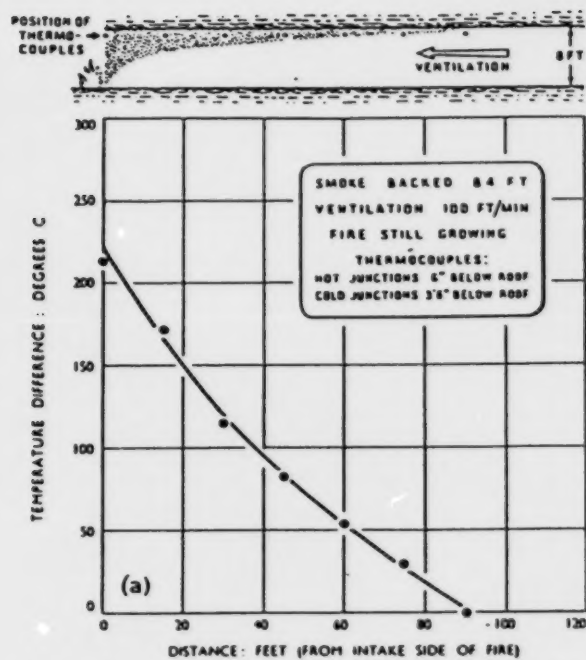
(d) Temperature

The temperature immediately downwind of a fire can be as high as 600°C and in some instances may reach 800°C. Higher than normal temperatures in the air current may extend as much as 1000m downwind of the fire. High temperatures together with smoke, toxic fumes and humidity make it impossible to mount a direct attack on a fire from the downwind side.

(e) Water Vapour and Humidity

All hydrocarbons produce water vapour during burning (and during oxidation as in spontaneous heating). The heat from a fire will vaporize the inherent moisture in coal as well as the water used to fight the fire and water from any other sources (i.e. damaged water pipes, soluble oil tanks). This produces extremely high humidities down-wind of the fire, even in briskly ventilated airways. High humidities also develop in sealed-off areas for the same reasons.

SMOKE BACK-UP TESTS



TEMPERATURE DISTRIBUTION IN THE ROOF
ON THE INTAKE SIDE OF A ROADWAY FIRE

High humidity limits a fire fighter's ability to sustain his work effort for more than short periods and the evaporative cooling systems on some types of breathing apparatus may be severely impaired.

6.5.6 Fire Fighting Problems

(a) Burning Methane

In the course of fighting fire, particularly where ventilation flow has been restricted to slow down fire progress, there is always the danger of ignitions of pockets or layers of methane. When these accumulations are ignited, the result is a burst of burning gas; the flame may even roll back over the fire fighters on the intake side. Experience to date indicates that the dry powder extinguishers are the most effective means of dealing with burning gas.

A burning gas layer may act as a "fuse" and carry a flame to other bodies of methane igniting them too. If these bodies of methane are in the gob or old workings and are inaccessible then sealing off may be the only alternative left, even though the original fire is being brought under control.

(b) Fire in Cavities

Fire above the roof supports or other inaccessible places is often difficult to attack because it is shielded behind light metal covering sheets. To remove these sheets manually is dangerous, unpleasant and time consuming. Fire fighters should have ready access to hand tools, i.e. long handled, light axes and scaling bars. There is also a most effective tool - the fire fighting lance. This is a 40mm diameter pipe that can be extended to 4m with screw connections. The fire hose can be coupled to one end of the lance; the other end has a hardened point with a pattern of nozzle holes. The lance can be thrust

through the metal lining sheets allowing water to be applied behind them. This device has been successfully employed on many occasions.

A device supplied by CBDC is the "Partition Nozzle". This device uses the pressure from the hydrant water supply to produce a high velocity, thin, water jet to cut through thin metal sheets, plywood or gyproc. The partition nozzle is part of the Fire Car equipment which is on permanent standby at the surface.

It is recommended that hand tools for fire fighting should be more readily available and these should include:

- . a long handled, light axe;
- . two scaling bars; and
- . a 'lance' that can be connected to the hoses.

The Partition nozzle provided on the fire car is a useful tool but it is strongly recommended that the simpler 'lance' should be provided in greater numbers underground, probably at the inbye and outbye ends of each production panel conveyor entry.

Another problem of attacking fires in cavities or dead-ends, is the lack of ventilation because the cavity is out of the general air stream. Hurdle cloths are a simple, readily prepared remedy but spray nozzles are effective too. In larger dead-ends an auxiliary fan or air mover might be needed.

In one incident in UK, burning wood and coal sides were being treated with water behind steel sheet lagging; after a few minutes the fire would re-ignite. The problem was solved by injecting a foaming cement/fly-ash mixture to fill the cavity. This brought the fire under control in a short time.

(c) Water Gas Ignitions

The action of water on incandescent carbonaceous material can result in a chemical reaction between the water (steam) and high temperature carbon to produce "Water gas", a mixture of hydrocarbon gases and which includes carbon monoxide and hydrogen. Water gas, when mixed with air is flammable. It is frequently ignited during fire fighting, particularly when digging out hot material from deep seated coal pillar fires and from spontaneous heatings.

Fire fighters should be made aware of the danger during their training programs. The best remedies are:

- . Apply water sprays and mists to cool down the fire, do not apply jets on red hot coals; and
- . Maintain at least some ventilation to disperse gases.

(d) Methane Pipe Lines

The existence and operation of methane drainage pipes in a section of the mine affected by fire raises questions about whether the drainage should continue, - bearing in mind that the pipe range may actually pass through the fire. Each situation will be different; hard and fast rules cannot be given and decisions will have to be made for each case.

However, the following aspects should be kept in mind:

- . The methane in the range is usually above the explosive limit and therefore will not ignite unless it mixes with air. The integrity of the pipe line is therefore important and, if possible, a check should be made to ensure that the methane in the pipe line IS well above the explosive limits.

- . Drainage pipes which are unconnected to vacuum pumps and which discharge into the air may do so in an area inaccessible due to the fire. If the methane in the pipe has been heated by the fire, it may be above ignition temperature when it is discharged into the air at the end of the pipe. It may be advisable to cool down the pipe line by playing water sprays on it to cool the methane.
- . If vacuum pumps are operating, the pipe range is under negative pressure and methane should not leak out.
- . The methane range and boreholes in a working district affected by spontaneous combustion, could provide a useful means of sampling to assess the progress of the fire. The system might also be applied to drawing off carbon monoxide as well as methane. However, if too much suction is applied, air (oxygen) can be drawn into the fire area to accelerate burning (this applies particularly to spontaneous combustion). Also, the methane in the pipe line may become diluted into the explosive range.
- . The hoses connecting drainage boreholes to the pipe line are destructible in a fire.
- . Methane pipe line joints should not rely on gaskets which can be destroyed by fire.

Careful pre-planning of methane drainage systems, careful drainage control during a fire and detailed assessment of "What if" cases before the event, help prepare for quick, safe decisions to be made in an emergency.

(e) Water Ranges

The water from a range which passes through a fire may have been converted to very hot water or steam. Training should make fire fighters aware of this possibility. Valves should be opened SLOWLY.

There are circumstances where it might be necessary to connect the water ranges of the intake and return entries by running a hose line through the face. Male/female connector converters are needed to do this and they should be provided at the inbye hydrant stations on each production panel.

(Note: circumstances such as -

- . Fire in a conveyor return entry,
- . Blocked or closed pipe line in top return entry).

This illustrates the value of RING MAIN SYSTEMS.

6.6 SPONTANEOUS HEATINGS

6.6.1 Introductory Remarks

The present mining operations in the Sydney Coalfield do not (and did not, over the last 14 yrs) present a spontaneous heating hazard. (R.N. Chakravorty, March 1984; "Spontaneous Heating of Canadian Coals During Mining and Storage - Problems and Potential Solutions"; CANMET Division Report ERP/CRL 84 - 14 (OP)) However, whenever coal is mined underground, there is always the possibility that unusual circumstances can combine to accelerate oxidation of the coal to the inception of spontaneous heating.

There are plans to renew underground coal mining in the Pictou area of Nova Scotia. Spontaneous heating was a major problem in the earlier underground mines of this area and interest in this subject may be renewed.

This section deals with spontaneous heatings in the context of fires. To deal fully with the complexity of prevention and control of spontaneous heating in detail is beyond the scope of this report.

When mine workings are prone to spontaneous heatings, it is not always the seam being mined that is the problem but it may be another band of coal or highly carbonaceous material in the roof or floor in close proximity to the coal being mined.

Different coals have different propensities to heat spontaneously which are increased by: -

- . pulverization of the coal;
(i.e. crushed pillars, crushed pillar edges, loose coal left in gobs)
- . presence of moisture; and
- . leakage air (supplying oxygen) at a flow sufficient to permit increasing rates of oxidation/burning, but not sufficient to carry away heat. Increased heat accelerates the oxidation rate.

The temperature at which the oxidation of pulverized coal begins to accelerate rapidly to a state of burning and incandescence, "the critical temperature", is around 70°C.

Among the principal means of avoiding the inception of spontaneous heating are the following:

- . Adequately sized pillars that do not crush.
- . Prevention of air leakage through gobs and around ventilation devices such as doors, air-crossings, stoppings and booster fans etc.
- . Good coal recovery from mining leaving the least possible broken coal and wood behind in the gobs.
- . Maintaining good sized roadways.

The symptoms of the development of a spontaneous heating are summarized in Figure 6.4.

One of the earliest signs of spontaneous heating is a detection of increased Carbon Monoxide content in the ventilation current down stream of the fire. However, locating the seat of spontaneous heating in its early stages can be difficult. By the time heat can be felt at roadway sides and a faint smoke haze is visible, the heating has reached an advanced stage. It should be kept in mind that spontaneous heatings burn **TOWARDS** the source of oxygen, i.e. towards the place where air is entering the heating zone. Heat, smell and smoke haze, appear where the products of combustion are **LEAVING** the heating zone.

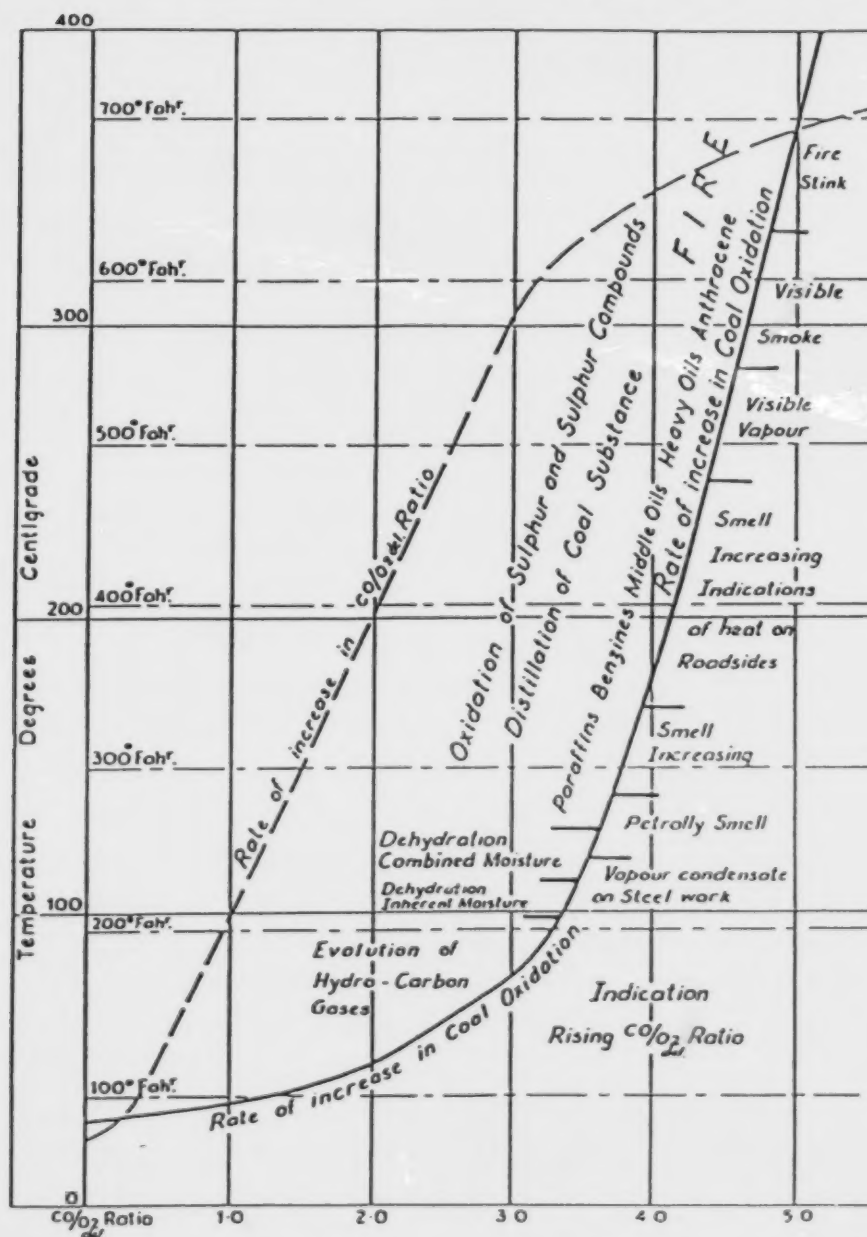
Although deep seated burning in a gob or pillar is usually the result of spontaneous heating it might also be left behind in the aftermath of fire which had spread into abandoned gobs or workings. The treatment methods are virtually the same.

6.6.2 Digging Out a Fire

This method is usually employed when it is believed that the position of the "hot spot" is known and that it is of a limited and manageable size. These assumptions may be ill-founded and lead to greater problems. The process is:

Figure 6.4

DEVELOPMENT OF SPONTANEOUS COMBUSTION



the more you dig, the more you are convinced that the "hot spot" is only another few inches into the solid. You dig on, creating a bigger and bigger cavity. As more ground is exposed the heating spreads; more water, sand, grout, cement and supports are required to support the cavity. Working in the excavation is extremely hot and unpleasant.

As an example; digging out a heating at an air crossing in a Staffordshire Mine (UK) resulted in 20 tons of material being dug out and replaced by sand.

Digging out should only be considered when the location is known with confidence and the quantity of material involved is finite and limited.

When digging out, one must be assured of adequate water supplies; sufficient manpower to allow for frequent rest periods; ample supplies of rock dust and sand; constant and accurate recording of carbon monoxide levels; continual temperature and hygrometer recordings.

Temperatures of the material being excavated may reach 1500°C. Provisions must be made for quenching and safely transporting the hot material to a suitable disposal site. The material dug out has a propensity for bursting into flames on its way out of the mine despite the fact that it has been soaked by water and covered with wet rock dust.

6.6.3 Smothering a Fire

Smothering is the term applied to extinguishing or reducing the rate of burning by excluding or greatly reducing the availability of oxygen. To do this the following techniques are used:

- . Roadway lining;
- . Strata Injection - Boogeeing;
- . Stopping off, or sealing off; and
- . Inerting.

These are indirect methods of fire fighting and, though not as positive and quick as direct fire fighting, they are safer and are the only means available when there is no direct access to the fire site.

(a) Roadway Lining

By applying an impervious lining to an airway, air is prevented from reaching the fire which is subdued by lack of oxygen. It is important to line the roof, sides, and sometimes the floor, at the suspected fire site and to continue the lining for at least 10m on each side of the sites where air is believed to be leaking into the fire, i.e., on the intake side. Air is able to travel long distances through tiny fissures and it is necessary to ensure that these are all sealed throughout the lined zone. The faces of leaking stoppings can also be sealed using lining techniques.

In one type of lining treatment, the roof and sides of the roadway are boxed in with a lining of boards or brattice and the sealing material packed in between the box lining and the roadside. The process is slow but effective. More often, the sealant is sprayed onto the roof and sides by machine. Many of

the materials adhere readily to the roadsides, but a layer of fine wire netting increases the liner's strength and stability; the application rate is approximately 1 tonne per hour.

Sand, being porous, is not a good lining material; cement, rock dust, clay and gypsum are better. Latex and vermiculite are sometimes added to spray-on materials to improve their adhesive and space-filling capacities respectively. It is necessary to repeat the treatment from time to time as the materials tend to crack or break away so re-admitting air.

Many lining methods are documented in a Symposium on the "Prevention of Spontaneous Combustion" - The Mining Engineer, 1970.

(b) Injection of Strata Breaks

This method, commonly known as "Bougeeing" is very effective in suppressing spontaneous heatings, and open fires, and as a fire preventative. It can be successfully applied from a remote distance e.g. from an adjoining gate road or from the surface.

The technique involves drilling through the strata to intersect breaks and cavities which are then injected with a filler material to consolidate the ground and prevent air reaching the fire via fissures and bed separation.

A systematic pattern of boreholes repeated over a length of roadway is more effective and quicker than a "hit or miss" plan. The boreholes are usually 4 - 5m in length, but considerably longer holes are also effective in some cases. The first 2 - 3m of each hole is drilled to a larger diameter; e.g. 60 mm so that a standpipe can be inserted. Drilling is at a smaller diameter for the rest of the hole.

The injecting is done by ram pumps from a mixing tank. Pressures ranging from 100 - 1000 p.s.i. are required and injection continues until the hole and strata becomes solid.

Various materials are injected. Water is not effective as it tends to open up fissures in the strata which then become air channels when the water drains away. Cement is also a poor material as it readily cracks and grinds up when set. Gypsum plaster is not effective as it reverts to a powder when strongly heated. Cement and stone dust mixtures have been popular and effective for many years, but now there is a variety of resins and stable gels for strata sealing and consolidation. They should be chosen and used carefully as they are expensive. Non-stable and reversible gels such as Bentonite tend to slump away in time and leave only a residue of fine powder if subjected to heat, their make up being about 85% water.

Due to strata movement and drying out, it may be necessary to 'top up' existing holes, or drill new ones, to maintain air tightness.

The act of bougeeing flushes out the gases in the breaks and cavities, and pollution of air currents may occur while injecting is in progress.

(c) Sealing-off and Inerting

These methods of containing and extinguishing fire are often complimentary. The techniques may be applied to all types of fire, not only spontaneous heatings. Sealing-off and Inerting methods are employed because the fire can no longer be brought under control by direct methods and all non-essential mine personnel will have been withdrawn to places of safety or the mine will have been evacuated completely.

6.7 THE LAST STAGES

6.7.1 Control and Direction of Operations

As a fire is being fought it is vital that communication is maintained with Surface Control and that the progress of the fire and its containment is reported accurately and frequently. It is VITAL that there is a competent Person-In-Charge (P in C) who has taken control at the surface, as provided for by the Mine's Emergency Plan.

It is also important that:

- . Officials in the mining sections report their position from a phone station and await instructions. They should not attempt to make ventilation changes or set off to explore on their own initiative.
- . Officials near the surface should report to Surface Control to be ready to make examinations of egress routes.
- . Senior officials of the mine DO NOT all hasten to the scene of the fire; perhaps two senior officials are sufficient. All the talents and experience of Senior technical people will be required at the central control to help direct the operations.

6.7.2 Polution of Airways

The roadways downwind of a fire may be impassable due to smoke, heat, toxic gases and fumes, and oxygen deficiency. This condition can develop until it extends to the surface of the mine. Mine surface entrances may be unapproachable. Due to leakage and ventilation derangements, (i.e. failure of a booster fan) smoke may even begin to pollute intake airways.

6.7.3 Loss of Services

While the fire is being fought, the progress of the fire may have resulted in some (or all) sections of mine being affected by:

- . damage to compressed air supply pipes;
- . damage to methane drainage systems;
- . loss of water supply to hydrants;
- . loss of electrical power supply;
- . loss of telephone communication; and
- . loss of environmental monitoring.

6.7.4 Explosion Hazard

During a mine fire, there is always the risk of a methane ignition which may lead to a coal dust explosion.

An explosion puts all men in the mine at deadly risk, therefore steps should be taken to evacuate all but those involved in fire-fighting as soon as possible.

6.7.5 The Decision To Adopt Indirect Methods

If direct attack is not gaining control over a fire then a decision has to be made as to when the direct attack efforts are to be abandoned. This decision has usually been arrived at in principle but is only implemented when certain conditions are reached; for example, abandoning direct attack methods as soon as preparations for constructing seals have been completed. Regardless of strategy, conditions may develop where direct-attack fire fighting crews have to be withdrawn. These conditions will be different in every case but will include the following:

- . When the fire clearly cannot be brought under control.
- . When the fire has spread to inaccessible areas.
- . When sampling or other signs, indicate the likelihood of an explosion.
- . When there is danger of the fire fighters escape route being cut-off by smoke, gases, heat, collapsed roadways etc.
- . When adequate communication with the fire fighters cannot be maintained.
- . When there is too little equipment and mine roadways at stake, to justify further risk.

6.7.6 The Use of Rescue Teams

The skills, facilities and services of Mine Rescue Teams are specialized and expensive. Every advantage should be taken of these specialties, but they should be used properly and economically.

The level of their involvement with increasing toxicity or threat is illustrated in Table 6.4.

Rescue teams should be used only where their breathing apparatus and or specialization is needed. To use Rescue Teams for fresh air work is wasteful. Also, Rescue Teams should be supported by fresh-air men as far as possible (i.e. fresh-air men move materials up to the Fresh Air Base, Rescue Men carry them into the polluted atmosphere.

The correct position for a Rescue Team in an emergency is at a forward post where they can become operational within minutes. It is pointless for Rescue Teams to be standing-by in a surface Rescue Room for hours.

**TABLE 6.4 - GUIDELINES FOR USE OF RESCUE TEAMS
DURING CONTAINMENT OF SPONTANEOUS COMBUSTION**

LEVEL OF CARB. MONOX. (PPM)	UNDERGROUND WORK USING FRESH-AIR WORKERS	INVOLVEMENT OF RESCUE TEAMS
0 - 15	NORMAL	NONE
15 - 50	NORMAL WORK BUT WITH INVESTIGATIONS UNDERWAY	RESCUE TEAMS ON-CALL.
50 - 100	PRODUCTION STOPPED IN AFFECTED MINE SECTIONS. CONTAINMENT OPERATIONS - I.E., LINING, BOOGEEING, SEALING.	RESCUE TEAMS ASSEMBLED AT MINE. RESCUE OFFICERS AND CAPTAINS BRIEFED. EMERGENCY PLAN SET IN OPERATION.
100 - 150	ALL PRODUCTION CEASES CONTAINMENT OPERATIONS GIVEN TOP PRIORITY.	RESCUE TEAMS ON FULL- ALERT AND ON OPERATIONAL STATUS. OR STAND-BY AT FRESH AIR BASE. RESCUE ROOM OPERATIONAL ROSTER OF TEAMS IN EFFECT.
150 - 250	FRESH AIR WORKERS IN POLLUTED ATMOSPHERE RESTRICTED TO CONTROLLED, SHORT DURATION TASKS.	ALL ROUTINE WORK IN POLLUTED ATMOSPHERE UNDER- TAKEN BY RESCUE TEAMS IN BREATHING APPARATUS WITH TEAMS STANDING-BY.
+ 250	NONE	ONLY RESCUE WORKERS IN BREATHING APPARATUS TO ENTER POLLUTED ATMOSPHERE.

Mine officials must recognise that Rescue Teams have special procedures and disciplines of their own from which they cannot be expected to depart. They operate on a team back-up system and standby teams should not be expected to do manual work during this time.

6.7.7 Fire Fighting Policy

The objectives in a major fire incident are, in order of priority:

- a) The saving of life.
- b) The prevention of further injury or loss.
- c) The containment of the incident.
- d) Minimizing the loss of mine areas and capital equipment, and
- e) The quick recovery to normal production.

From the early stages of the incident it is necessary to adopt a strategy which is directed towards achieving these objectives. The strategy may have to change to meet changing circumstances.

Experience in Europe over many years has shown that a "correct" fire fighting strategy or method is not as critical as might be believed. The technical sections of this Report comment on many alternative treatments of fires but, providing a method is carefully and logically chosen, it will have as good a chance of success as the alternatives - PROVIDING IT IS EFFICIENTLY AND RESOLUTELY CARRIED OUT.

The greatest dangers and ineffectiveness result from half-hearted attempts at several methods at once or changing methods frequently without deep consideration. Irresolute wavering dissipates available resources and manpower; nothing is done properly and the battle is lost.

The success of a fire fighting/containment operation is important to save life, allow men to escape, and to save sections of (in some cases the whole of) the mine. During combat with the fire, there are critical moments in which opportunities for decisive and successful action present themselves. These opportunities must not be lost through indecision, delays, lack of supplies etc. A policy of "OVERKILL" should be adopted. The added costs are minimal compared to the cost of a lost opportunity and a failure to control the fire.

If 60 tonnes of rock dust is requested - send 80 tonnes;

If 12 hoses are asked for - send 20;

If 10 Rescue Teams are believed sufficient - arrange for 12.

The consequences of losing control of a fire due to underestimating the need for services, supplies and reinforcements are inestimable.

7.0 EVACUATION OF THE MINE

7.1 INTRODUCTION

The circumstances and conditions of every mine fire are different therefore comment, for the most part, must be of a general nature.

Evacuation is usually carried out in stages depending on the location and progress of the fire. The first stage is a withdrawal of persons immediately threatened by the fire. They retire to a place of safety, usually a main intake airway, from where they can return to the surface quickly in unpolluted air.

From the moment a fire is discovered, the factors which contribute to successful evacuation are:

- . Decisiveness
- . Preparedness
- . Transportation
- . Communication

7.2 DECISIVENESS

7.2.1 First Discovery of Fire

The decisions taken on first discovering a fire are probably the most critical ones. Much depends on the nature of the fire and who discovers it.

Alerting Others

Whenever a fire is discovered, everyone in the mine should be alerted as quickly as possible. Those sections of the mine likely to be affected by smoke or cut off should be evacuated immediately. The Supervisors of these sections should direct their crews to a main intake assembly station which will be free from smoke pollution.

This means that communicating the emergency must receive first priority.

If the discoverer is alone, he must: -

first: Inform the surface control who will warn others and arrange for help;

second: Get the help of others if others are nearby;

third: Do whatever can be done without undue personal risk, until help arrives.

If the discoverer is not alone then preparations to combat the fire can start immediately while surface control is being informed.

Nature of the Fire

If the fire is an open-flame fire (perhaps involving roadway support timber) speed in getting water onto the fire is vital. On the other hand, if the fire is a slow, smouldering fire (perhaps concealed smouldering of coal in spillage piles or of a coaly floor under a conveyor belt) then it may well be better to delay fire combat until personnel who might be affected have been withdrawn. A smouldering fire can rapidly escalate when disturbed. It is better to wait for partial evacuation to be completed using the time delay for preparing hoses and getting large quantities of stone dust to the site.

If the fire involves electrical equipment or smouldering belt at a conveyor drive, it is possible that the smoke and fumes will prove to be more alarming and unpleasant, than dangerous. The sooner the power supply is cut off and the fire-site cooled down, the sooner will smoke generation cease.

These examples serve to illustrate that decisive and knowledgeable action on the part of the fire discoverer, the control room operator, mine section supervisors and senior mine officials is of paramount importance.

The Discoverer

The discoverer of a fire is most likely to be a workman, mine examiner or supervisor. Ground rules for initiating partial evacuation should have been established that will support him in his immediate actions; it should be well publicized what these ground rules are.

Knowledge and training are the bases of confident decisions; confident decisions constitute decisiveness. It is indecision that sets off uncoordinated actions and arouses apprehension.

7.2.2 Whom Should be Evacuated and When?

There is often a commendable refusal by underground coal miners to be alarmist, however, it is probably prudent to always commence partial evacuation as soon as fire is reported. This means withdrawing people from the parts of the mine likely to be affected and also THOSE EMPLOYED IN THE EXTREMITIES OF THE MINE, such as development and salvage works. It is better to err on the safe side where mine fire is concerned.

Partial evacuation is the first stage of evacuation, in which people not required to combat the fire are assembled at a safe, intake location from which the surface can readily be reached. In CBDC mines this would probably be at the bottom of the intake slopes serviced by a man-trip hoist system.

A number of fire combat teams will be formed, sufficient to offer rest periods while sustaining an "all-out" fire combat effort. In addition to those directly fighting the fire there will be a need for support teams who will be employed to supply fire fighters with stone dust, fire fighting equipment and other necessities.

If the fire is successfully extinguished people can return to their working places; if not, those not required for fire fighting should travel to the surface and report their safe exit from the mine.

If the fire continues senior officials at the mine will order a general evacuation in which case all but those engaged in fire fighting will leave the mine. It would be a rare and serious event which would demand an immediate and complete evacuation of all personnel from the mine. In such cases fire fighting continues until evacuation is complete, after which fire fighting teams abandon their efforts and return to the surface.

7.3 PREPAREDNESS

7.3.1 Marking Exit Routes

Although most underground employees are familiar with the mine's layout and ventilation system, exit routes to the surface are signposted to cater not only for new employees but also for the disorientation caused by poor visibility due to smoke. In CBDC mines the exit routes are clearly marked by reflective arrows

which have good visibility, even in a smoky atmosphere. Entrances to old workings and other openings should be stopped off to prevent inadvertent entry.

There is no doubt that the greatest obstacle to a safe exit from a fire affected mine section, is smoke and poor visibility. The natural urge to travel quickly and the inability to see, creates disorientation and panic. This is less likely if evacuees travel in groups.

It would also help if panel entry distances were marked at, say, 100 m intervals by reflective plates. Evacuees could then be re-assured of their progress towards the main entries.

7.3.2 Self Rescuers

Two types of self rescuers are in common use, the filter type which is small and carried on a miner's belt and the oxygen self rescuer which is too cumbersome to be carried by the miner throughout his shift. The procedure adopted in CBDC mines is to store the oxygen self rescuers in dust proof containers placed in steel baskets at suitable vantage points near the working places. The filter self rescuers offer protection from smoke and carbon monoxide providing the atmosphere contains enough oxygen to sustain the wearer. They will undoubtedly help the wearer to reach the oxygen self-rescuers.

An oxygen self-rescuer will last about 45 minutes if the wearer is walking or exerting moderate, physical effort. If the wearer is at rest, it will last twice as long. The purpose of self-rescuers is to enable evacuees to continue making their way to fresh air and the surface even when the air is full of smoke, contains dangerous levels of carbon dioxide and monoxide and which may be seriously deficient in oxygen. Travelling through

smoke, when visibility is very poor, is a slow process; an oxygen self-rescuer gives the wearer some time in which to get out of his district and into intake air.

The panel entry distance that a man might have to walk in the CBDC mines could be as much as 2,800 m (No.10 East, Lingan Mine). At normal walking speed this would take about 45 minutes - the rated duration of the oxygen self-rescuer.

If evacuees are able to avail themselves of man-riding facilities in the panel entry, the oxygen supply is quite sufficient. However, if the man-rider is not available and smoke impedes travel, then the oxygen self-rescuers would be inadequate.

It is recommended that, where panel entries are more than 1500m in length, the 60 minute type oxygen self-rescuers be used or, a supply of replacement 45 minute oxygen self-rescuers be located not more than 1500 m in from the start of the entry.

7.3.3 Refuge Chambers

Effective refuge chambers are constructed in strong, non-carbonaceous strata and fitted with fireproof, concrete, end walls with strong steel doors that can be sealed air-tight by means of wet clay. (See the CANMET Report "Survey and Assessment of Mine Rescue Programs" - Project No.430211, April 1983).

The inside of refuge chambers are furnished with:

- . oxygen self-rescuers
- . tables and benches
- . first aid supplies and extinguishers

- . drinking water and food
- . chemical toilet
- . blankets
- . pencils and paper.

The volume of the chamber depends on the expected number of occupants and how long they will be inside. For a 24 hour refuge, a design volume of 18 m³ per person is suitable.

The chamber is provided with a compressed air line, which enables the chamber to be slightly pressurized to prevent smoke and fumes entering and to provide an air supply. If the compressed air lines are undamaged by the fire, the air supply is indefinite. As a back-up, the chamber is also provided with compressed air bottles which can be used to pressurize the chamber and provide a limited amount of air. The 18 m³ per person volume for 24 hours refuge, assumes persons at rest and no other source of air.

The chamber will have, in addition, a water pipe-line, telephone and lighting, but these services could be cut off by the fire.

The useful application of refuge chambers in the Cape Breton Mine is worthy of some consideration due to the long travelling distance from the faces to the surface. However, there are a number of contentious issues such as:

- . selecting suitable locations
- . formulating a policy (i.e. one large chamber; numerous small ones)
- . determining size
- . assessing cost versus use (cost could be in the region of \$10,000 per man-day capacity)

If the surroundings and approaches to a refuge chamber are ravaged by the fire itself, it is unlikely that rescuers will be able to reach the chamber and bring out survivors. It should be recognized that the most effective use of the chamber will be as place of refuge from fumes and hot smoke. This should be kept in mind when considering suitable locations.

It might be expected that, following an alarm, most persons will have immediately left their working places to make their way to the bottom of the main slope man-trip. It might also be expected that the intakes will remain smoke free but, in later stages of a fire, both the intakes and the man-trip waiting stations could become untenable by reason of hot smoke. The persons most likely to be affected would be the fire fighting crews and any evacuee stragglers who would be the last to reach the man-trip.

If CBDC were to consider constructing a refuge station, it is suggested that a site adjacent to the bottom of the intake man-trips should be considered first. The chamber could be driven back horizontally parallel to the slopes, and into the floor rock of the seam. Here, refugees could await man-trips, clear of the smoke and heat. When the cars arrived, they would have to rely on their self rescuers, the protection of the man-rider car and any protective clothing which might be stored in the chamber, to make a safe ascent to the surface.

It is suggested that a 30 man-day chamber would be a suitable size, its dimensions being in the order of:

width	4 m
height	3 m
length	<u>45</u> m
volume	$540 \text{ m}^3 (= 30 \times 18 \text{ m}^3)$

7.3.4 Pre-Planning

Pre-planning is an important ingredient of preparedness. It begins by looking at possible development of fires at a mine together with a series of "what if" circumstances. These exercises serve to highlight potential problem areas and the ways in which they can be avoided or dealt with. Rules and guidelines related to evacuation can be developed ready to be put in operation if an emergency arises. These guidelines should address, for example, the procedures to be adopted by locomotive drivers and rope haulage operators in relation to:

- . providing manriding services out of the mining sections;
- . preparing to transport fire combat materials; and
- . operating the equipment in smoke.

Similarly, the operation of belt conveyors; should the operator stop them or leave them running when he evacuates his post? A conveyor left running might offer life saving transportation for someone. Should pumps and fans be left running to maintain normal conditions as long as possible?, they can often be monitored and remotely operated from the surface or have their power cut off at the main sub-stations when all have left the inbye mine sections.

A lot of important decisions can be considered carefully and unhurriedly before hand, instead of during the stress of an actual fire when quick decisions must be made and instructions given.

Pre-planning of evacuations should also take into account those circumstances when orderly evacuation is overtaken by a sudden event, such as an explosion caused by the fire. In these cases the behaviour of evacuees is unpredictable but experience has shown that the following generally applies.

- . Men will struggle to reach what they believe to be fresh air - the usual intake airways.
- . In about 90% of cases men will travel with the ventilation current i.e. "driven before the smoke". For some reason, in about 10% of cases, men travel into the smoke and are therefore at special risk because they are travelling towards the seat of the fire which is usually impassable.
- . When driven before the smoke, men will attempt to go anywhere to reach fresh air and often go to shafts and old accesses, into old workings (often a considerable distance) and even towards surface subsidence cavities. All these places must be thoroughly searched by rescue parties when looking for survivors.
- . If escape is impossible, men will attempt to enter a blind end, a heading or even a cavity, and seal themselves in, with whatever material they can find, to keep out smoke and preserve a life sustaining atmosphere. It has been known for men to survive for long periods in this manner.

7.4 MAIN SLOPE TRANSPORTATION

7.4.1 Introductory Remarks

Ingress and egress at all three CBDC mines is by means of electrically powered rope haulages down slopes from the surface. At Lingan there three direct rope hoists,

- . in No.4 slope - intake
- . in No.3 conveyor slope - intake
- . in No.2 slope - return

At Phalen there are three direct rope hoists,

- . in No.2 conveyor slope - intake
- . in No.3 slope - intake
- . in No.4 slope - intake

At Prince there are two haulages,

- . No.5 deep intake - men and materials, direct rope
- . No.3 deep intake - manrider, endless rope.

The steepness and length of these slopes or deeps, is such that, in an emergency, manriding must be provided to get men out of the mine quickly and safely. All the hoists are at the surface where they will be unaffected by a mine fire. The electric hoists at Lingan and Phalen have locomotive generators as a back-up power supply.

Prince mine relies on a diesel generator which can supply enough power to run the hoist or the fan (but not both).

7.4.2 Speed of Hoisting

The operating speeds for the haulages (manriding and supplies) is between 10 and 12 km per hour (= 180 m/min.).

At Lingan and Prince mines a one-way journey normally takes from 20 - 24 minutes. The maximum number of men underground is at Lingan, 300 on the day shift. The maximum at Phalen and Prince mines is 180, also on the day shift. With 5 car trips carrying 30 men/car, 300 can be raised to the surface in two trips. If this is two simultaneous trips on two hoists, 300 can be brought to the surface in about 24 minutes. Since all mines have at least two hoists in intakes this capacity appears to be adequate. However, it is assumed that the trips are at the bottom and waiting.

Even though 24 minutes trip time can be considered adequate, it is obviously an improvement if the journey can be safely done faster.

The hoists are capable of higher speeds but the track should be carefully examined and, if necessary, up-graded before the higher speeds are used. However, some resistance was reported, on the part of both mine management and employees, against going to higher speed man-trips. One advantage of the higher speeds is that passengers would have less exposure to smoke if smoke had entered the main intake.

Enclosed, sealed, manriding cars would protect passengers when passing through smoke and heat. To convert the present cars to being protectively enclosed would not be difficult. The cost benefit of such adaptations is reduced by the fact that, with two or more hoists in intake airways the chances of them both being rendered unusable is remote. In any case, passengers could still use their oxygen-self rescuers.

Another option would be to ride up the conveyor intake on the belt. This is normally forbidden as unsafe and belt riding should be a last resort. During evacuation, groups should keep together with their respective supervisors and, so far as possible, travel the approved evacuation routes. Individuals should be strongly dissuaded from using the belts unnecessarily to exit the mine though outright prevention might prove difficult.

7.5 COMMUNICATIONS

7.5.1 Reporting a Fire

As soon as any kind of burning or heating is noted it should be reported to the control room even though it may appear to be trivial. As was noted in 7.2.1, it is as important to report the fire as it is to start extinguishing it. No evacuation will be put in motion unless a fire danger has been reported. The importance of this aspect must be stressed in all fire fighting training and induction courses for new employees.

7.5.2 Raising the Alarm

When a fire has been reported, no matter how small, the control room operator must arrange to pass on the information to all sections of the mine. He will normally do this by telephone and should ensure that he speaks with the supervisor, even though the supervisor may not be the first person he contacts. When contact is established, arrangements should be made to ensure that contact can be maintained. This probably entails having someone posted at the phone to receive messages and relay them to the supervisor.

A call for partial evacuation will be transmitted by phone but backed by signals on speaker phones and conveyor start-up warning horns. Supervisors should report their progress out of their sections at each phone on the evacuation route.

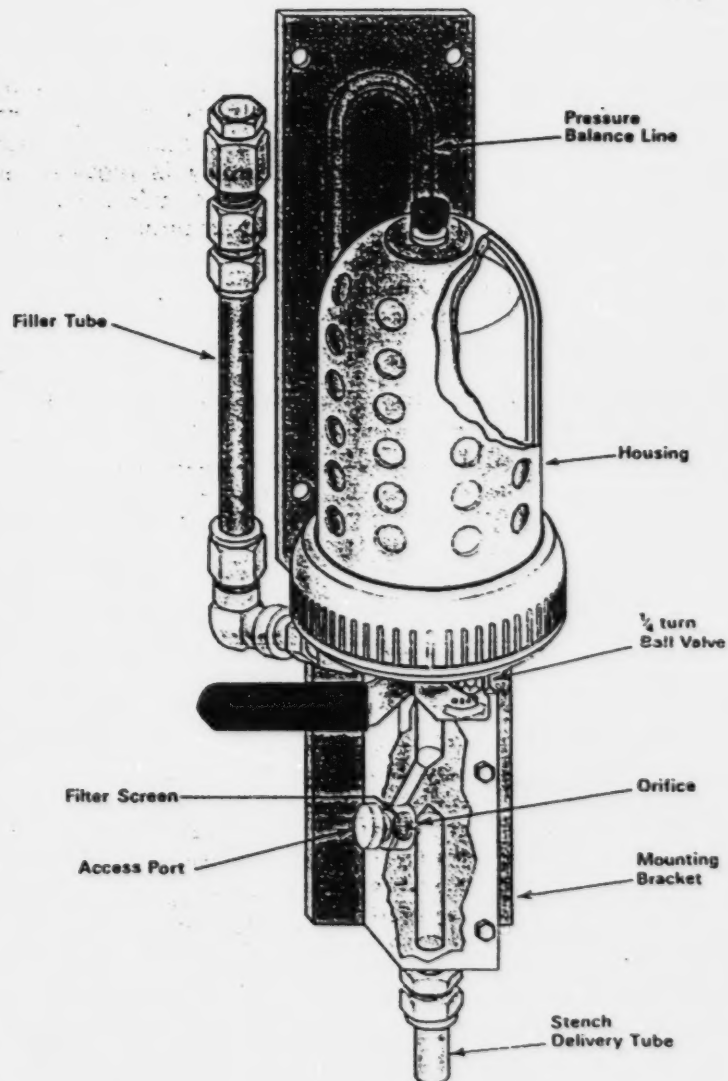
The control room operator will need assistance in answering phones, relaying messages, and recording the time and message content of all ingoing and outgoing calls.

7.5.3 Call for General Evacuation

If a general evacuation is called for, actions should be proceeding according to the mine's Emergency Plan. Communicating the emergency to all persons in the mine is most important. Loudspeaker systems as used by CBDC make contact with fixed points comparatively easy. In addition simultaneous conversations or instructions can be passed on to many people at the same time. A special tone can be incorporated into some systems to indicate emergency.

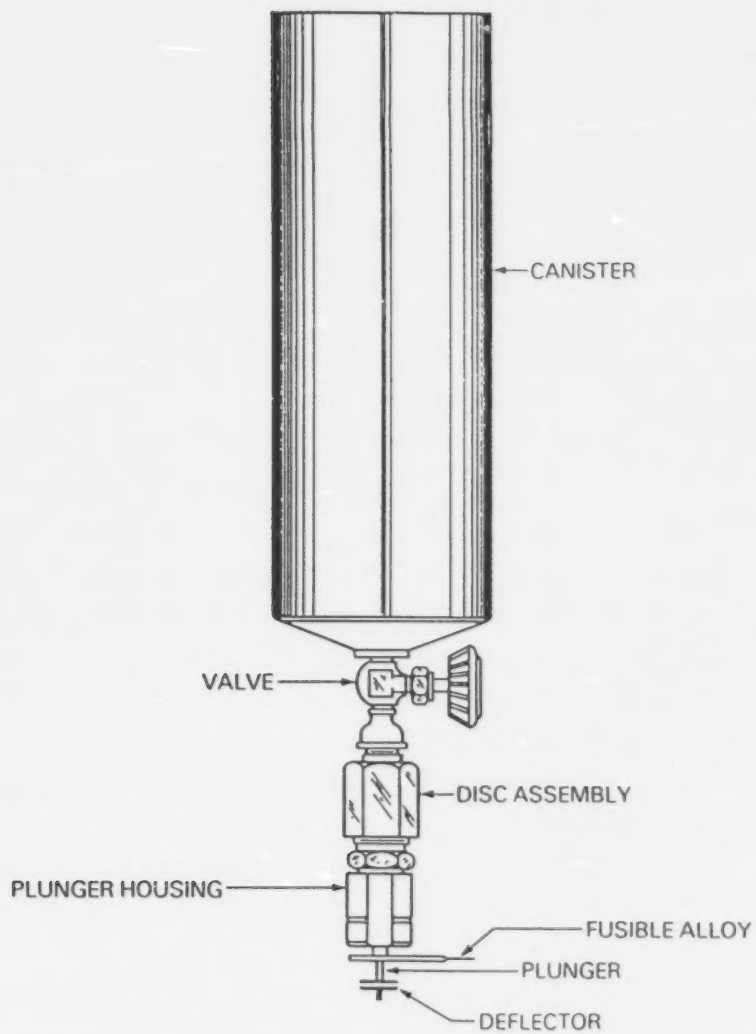
Radio communication using the Leaky Feeder system is very useful for contacting moving vehicles. Some have recently been installed by CBDC on their main slope manriding hoists and should be made available on all of them.

Stench warning systems are commonly used in hard-rock mines by being released into the compressed air lines. Stench warnings have not been favoured by coal mines mainly because it would rely on the ventilation to carry the stench and this is not considered to have the necessary speed and reliability. A stench warning device located in remote areas of the mine could be set off manually or by remotely operated devices. (See Figure 7.1). It could be used to warn people who are in remote areas of the mine and who may not always be near a telephone.



Graphic depicts manual stench injector and its major components.

FIGURE 7 - 1



Schematic of stench gas-tracer fire warning canister.

FIGURE 7 - 2

This would include development heading workers, conveyor cleaners/examiners, repair men, salvage men and airways examiners.

Ethyl Mercaptan is the chemical commonly released to produce the stench. A new chemical, Tetrahydrothiophane (THT), has been approved by the U.S. Bureau of Mines and this is now replacing the Mercaptan.

Stench warnings can be triggered by heat (see Figure 7.2) but the carbon monoxide sensors on CBDC's environmental monitoring system are more sensitive and provide earlier warning both at site and in the control room.

8.0 INDIRECT METHODS OF FIRE CONTAINMENT

8.1 INTRODUCTORY REMARKS

8.1.1 Definition of Terms

Indirect methods of fire containment fall into two main categories -

- . The introduction of inert gases such as Nitrogen, (N_2) and Carbon Dioxide, (CO_2).
- . The construction of seals or stoppings to enclose the fire area.

In some cases the two methods together are employed, i.e. constructing seals and introducing the inert gas behind them. The term "Inert Gases" is loosely used in this context to mean gases which are incombustible and which do not support combustion. Another term is also used - "Extinctive Atmosphere". An extinctive atmosphere is not necessarily inert. However, it is termed extinctive because, whatever mixture of gases it contains, e.g. Nitrogen, Carbon Dioxide, Methane - its oxygen level is so low that it will not support combustion or life; fire will be extinguished (hence "extinctive atmosphere").

8.1.2 Danger of Re-Ignition

Although a fire may have been extinguished by creating an inert or extinctive atmosphere, it is well to remember that, in the fire zone, "hot spots" may remain at ignition temperatures for a long time, particularly where spontaneous combustion has occurred and where fire has penetrated deeply into coal pillars or into thin coal seams in the roof or floor. The re-admittance of air into the area (perhaps by breaching seals and attempting to re-establish ventilation) -if done too soon, can be very

dangerous, especially if the fire is re-activated in an area where concentrations of methane gas are likely to have formed.

8.2 INERTING - THE USE OF INERT GASES

8.2.1 Suppliers of Inert Gases

Two types of gas are used, Nitrogen (N_2) and Carbon Dioxide (CO_2). Both these gases are employed in the oil and gas industry for controlling the flammability of petroleum based fumes and natural gas, and in refinery operations. To control coal mine fires in Canada, Nitrogen has been used (Sydney, N.S. 1984). Principal suppliers in Canada are: -

- . Union Carbide Canada Ltd.
 - Linde Division, Fort Saskatchewan, Alberta
- . Canadian Liquid Air - with production centres in Alberta, Saskatchewan, Manitoba, Hamilton (Ont.), Montreal, and Moncton (N.B.).

The costs of gas are very high, in the region of \$850/tonne plus transportation.

8.2.2 Handling and Storage of Inert Gases

The Inert Gas is transported from manufacturers' plants in tanker trucks or rail tankers, specially designed to carry the gas in bulk liquid form at very low temperatures, (less than $-185^{\circ}C$ for Nitrogen). In cases of emergency, it is necessary to seek the cooperation of appropriate Provincial authorities to waive certain load restrictions. It is also necessary to enlist the services of a company with the expertise and equipment to receive, store at the mine and prepare the liquid gas for piping underground.

It is virtually impossible to mount a production, transportation and handling process, to deliver large volumes of N_2 or CO_2 at very short notice in an emergency. However, contingency plans can be prepared which would speed up the organization of supplies.

Further information on the supply and handling of inert gases can be obtained from the following papers given at the "Confined Space fire Suppression and Rescue Conference", organized by Alberta Occupational Health and Safety Division, Edmonton, March 1985.

- . Application of Inert Gas, D.L. Grombie, P. Eng.
NOWSCO WELL SERVICE LTD.
- . Inert Gas Supplies in Western Canada and North Western U.S.A.,
Jim Sweetman, CANADIAN LIQUID AIR LTD. (Calgary)
- . Inert Gas Useage in the Petroleum Industry, Glenn D. Bowman,
UNION CARBIDE CANADA LTD. - Linde Division.

At a mine site the N_2 (CO_2) is pumped into insulated storage tanks. The boiling point of N_2 is $-196^\circ C$ therefore there is a continuous loss of gas due to vaporization during transit and storage; all containing vessels are provided with pressure control valves which release the pressure as the gas expands during warming. It is impractical and too costly, to expect that large supplies of gas can be permanently stored at site.

Special pumps are required to transfer the liquid gas from the storage tanks to a Vaporizer or heat exchanger. "Cooling down" of the pumps takes about half an hour before vaporizing can be started.

The liquid gas is pumped into the heat exchanger and discharged at temperatures which can vary from - 40°C to over + 80°C; for fire control, the colder the better. Vaporizers are usually heated by diesel being semi-mobile, skid mounted, oil field equipment. From the vaporizer the gas is conducted through underground pipe lines at pressures from 550KPa to 850 KPa (80 - 120 psi)

The following tables show: -

Table 8.1 Typical Nitrogen Handling Equipment. Available in Canada.

Table 8.2 Typical Carbon Dioxide Equipment. Available in Canada.

Table 8.3 Metric Conversion factors for N₂ and CO₂.

D.L. Crombie, (NOWSCO WELL SERVICE LTD.) recommends that Mine Operators should familiarize themselves with:

- . who supplies and pumps the inerting gases; their location, and equipment types available.
- . the equipment involved in inerting with N₂ and CO₂, specifically sizes and capacities.
- . piping within the mine; specifically - diameters, pressure limitations, location of inlet and outlet points and types of fittings.

TABLE 8.1

TYPICAL NITROGEN HANDLING EQUIPMENT AVAILABLE IN CANADA

Description of Equipment	Self Contained Tank Capacity of Unit m ³ (SCF)	Pump Capacity of Unit m ³ /min (SCF/min)	Size of Unit m (ft)			Unit Weight kg (lb)	
			H	W	L	Empty	Loaded
Yard storage tank	45,200 - 129,000 (1.6 m - 4.6 m)	-- (--)	N/A	N/A	N/A	N/A	N/A
Bulk transports	9,900 - 17,000 (350 m - 600 m)	-- (--)	3.7 (12)	2.4 (8)	18.3 (60)	16300 (36000)	36,400 (80,000)
Remote storage tank skids	5,330 - 40,000 (188 m - 1.42 m)	-- (--)	2.4 (8)	2.4 (8)	4.4-13.7 (14.5-45)	3000-25000 (6600-55000)	10000-71000 (22000-156000)
Skid mounted pumps							
low rate	-- (--)	28 (1000)	1.0 (3)	2.0 (6)	2.0 (6)	4500 (10000)	N/A
intermediate rate	-- (--)	85 (3000)	2.4 (8)	2.4 (8)	4.7 (15.5)	5500 (12000)	N/A
high rate	-- (--)	127 (4500)	2.4 (8)	2.4 (8)	4.7 (15.5)	5500 (12000)	N/A
Truck mounted pumps							
low rate	1530 (188 m)	85 (3000)	3.7 (12)	2.4 (8)	9.1 (30)	15900 (35000)	21800 (48000)
high rate	7000 (248 m)	170 (6000)	3.7 (12)	2.4 (8)	19.8 (65)	16800 (37000)	36400 (80000)

TABLE 8.2

TYPICAL CARBON DIOXIDE HANDLING EQUIPMENT AVAILABLE IN CANADA

Description of Equipment	Self Contained Tank Capacity of Unit m ³ (SCF)	Size of Unit m (ft)			Unit Weight kg (lb)	
		H	W	L	Empty	Loaded
CO ₂ transport	10,200	3.4	2.4	18.3	13,400	37,000
	(360 m)	(12)	(8)	(60)	(31000)	(82,000)
CO ₂ storage tank	24,300	3.0	3.0	13.7	24,000	69,400
	(861 m)	(10)	(10)	(45)	(53,000)	(153,000)

TABLE 8.3

METRIC CONVERSION FACTORS FOR N₂ AND CO₂1. Nitrogen

1 scf	=	0.02826245 m ³ gas
1 scf/bbl	=	0.177765 m ³ /m ³
1 m ³ liquid	=	808.41 kg liquid
	=	694.4 m ³ gas

1 gal, liquid	=	6.8 lb
1 lb, liquid	=	93.0 scf
1 scf gas	=	13.7 scf
	=	0.0724 lb.

N₂ liquid data at approximately -196°C.

N₂ liquid data at approximately -320°F.

2. Carbon Dioxide

1 scf	=	0.02826245 m ³ gas
1 scf/bbl	=	0.177765 m ³ /m ³
1 m ³ liquid	=	1017.31 kg liquid
	=	543.7 m ³ gas
1 m liquid	=	9.976 kPa (hydrostatic)

1 bbl liquid	=	335 lb. liquid
	=	3070 scf gas
1 ft. liquid	=	0.44 psi (hydrostatic)
1 gal liquid	=	8.46 lb. liquid
	=	74 scf gas
1 lb. liquid	=	0.0028 bbl liquid
	=	8.61 scf gas
1 ton, liquid	=	5.61 bbl liquid
	=	17200 scf gas

Above factors for liquid CO₂ conditions of -180°C and 2070 kPa. At -290°C, liquid density increases approximately 5%.

Above factors for liquid CO₂ conditions of 0°F and 300 psi. At -200°F, liquid density increases approximately 5%.

8.2.3 Application of Inert Gases

The use of inert gases as a means of controlling a mine fire is now a well established technique. Nitrogen was used to combat the fire at the No. 26 Colliery in April 1984 at a cost of over \$800,000. Since that time the Lingan, Phalen, and Prince mines have arranged for existing pipelines to be made available to convey nitrogen into the mine, in an emergency. In addition, standage room is held ready at the surface to accommodate tankers and evaporators.

A seminar on Inerting Techniques was held in Sydney N.S. in September of 1984 and inerting methods have been appraised in the U.K. and in Germany. The techniques have the advantage that most of the operation is controlled from the surface. The gas is conducted underground in pipe ranges, typically 150mm in diameter or down boreholes.

The effects of introducing Nitrogen to a fire site are two fold:

- . the availability of oxygen is reduced thereby retarding the rate of burning (or oxidation in the case of a spontaneous heating).
- . its low temperature brings down the temperature of the fire.

The inert gas can be used in the following ways:

- (a) It can be released freely in a roadway and allowed to pass into an active fire area. This reduces burning and "buys time" for alternative measures to be employed. To be effective, high rates of inert gas release are required. Care must be exercised to avoid the risk of workers on the downstream side of the fire experiencing oxygen deficiency.

- (b) It can be used to control spontaneous heating in the gob of a working longwall face. The nitrogen is released continuously at the waste edge and allowed to flow into the heating area. The progress of a heating may be arrested in this way but rarely extinguished. Inert gas release may have to be continued for many months at flow rates varying from a low of $5\text{m}^3/\text{min.}$ up to, and possibly beyond, $30\text{m}^3/\text{min.}$ The flow is regulated according to the measured levels of carbon monoxide issuing from the heating zone.

This method of controlling a longwall heating allows production to continue until a panel is mined out or until alternative control methods (such as lining or boogeeing) can take effect. It is a costly remedy but generally less costly than losing development face room and suffering a disrupted production schedule.

- (c) Inert gas can be introduced behind the seals of a stopped - off fire area to hasten the development of an extinctive atmosphere. It can also reduce the possibility of the atmosphere becoming explosive (due to the presence of methane) while an extinctive atmosphere is developing. In one instance, an injection of nitrogen dramatically reduced the oxygen content in a sealed area from 18% to 0.3% in a 24 hour period (Bibliography Ref. 13).

Typically, a sealed off area would become extinctive within 2 to 3 days without the expensive addition of inert gas; its use should therefore be contemplated with due regard for cost. Inerting is most cost-effective when used to extinguish fire by replacing oxygen, but when high concentrations of Blackdamp and methane exist, there is little point in replacing one extinctive atmosphere with another.

Nitrogen, up to now, appears to be the preferred inert gas in Canada but Mr. Froger, of the Centre D'Etudes et Recherches de Charbonnage de France, described a dramatic example of the use of Carbon Dioxide to suppress a conveyor fire in a rock drift in France. Carbon Dioxide has nearly twice the density of air and can therefore be "poured" downhill into shafts and inclines where it resists thermal circulation because of its density. In coal mining, permanent CO₂ installations might be considered as a measure against fires in moving bed bunkers, strata bunkers and staple shafts. Carefully designed methods of control and containment would be necessary since CO₂ is a toxic gas.

Inert gases can greatly diminish the risk of explosion when flushing out a methane-laden atmosphere when re-establishing a mine section after breaching seals. If the sealed area contained, for example, an atmosphere which included 60% methane and 5% oxygen then, if the section was flushed out by air, the atmosphere would pass through the explosive range of methane as it was being diluted. If Nitrogen was used instead of air, most of the methane could be safely removed leaving an atmosphere containing perhaps 10% methane, 1% oxygen and 89% Nitrogen. This mixture can be safely flushed with air without entering an explosive range. (See section 9.0 dealing with gases and the application of the Coward Charts).

8.3 SEALING OR STOPPING-OFF (INDIRECT FIRE CONTAINMENT)

8.3.1 Introduction

The purpose of stopping-off is to prevent the ingress of air (oxygen) to a fire. The available oxygen in the area enclosed by the seals is consumed by the fire until there is insufficient oxygen left to support combustion and the fire is extinguished. The remaining atmosphere is then extinctive. The burning produces CO_2 and, as the oxygen supply diminishes, CO . As the oxygen is consumed the proportion of N_2 in the atmosphere increases. The inert mixture of N_2 and CO_2 is referred to as "Blackdamp". While the fire is gradually being extinguished methane continues to be given off from the coal seam and surrounding strata. Some of the methane will be burnt by the fire, in the early stages following sealing-off but later, as the fire goes out, the methane percentage will start to rise. The humidity will also rise since steam is one of the products of combustion.

The dynamic changes in the composition of the atmosphere behind the seals are used to assess:

- . the effectiveness of the seals to prevent the ingress of air.
- . the state of the fire and its progress towards extinction.
- . the danger of explosion behind the seals - This is particularly important during the construction of the seals.

Once seals are in place there is no further access to equipment left in the sealed area and ventilation of other sections of the mine may be made more difficult. However, in spite of the loss of reserves and roadways, there is usually no alternative to sealing-off once a fire is beyond control by direct means. The advantages of seals are -

- . Once seals are in place the rest of the mine can usually resume operations.
- . In certain circumstances - and after an adequate "cool-down" period, the affected section of the mine may be re-opened and reserves (sometimes equipment) recovered.

There is no limit to the size of area that can be sealed-off. However, it is desirable to minimize the area to keep reserve and equipment losses to a minimum, to preserve the mine as a productive unit and to minimize the time required for an extinctive atmosphere to develop. Additionally, the smaller the area, the fewer, usually, are the number of stoppings required to seal it. It is not unusual for large areas of a mine to require as many as 12 stoppings to be constructed and the area is very prone to leakage. Comment has been made on selecting the sites for seals in Section 6.4.3.

8.3.2 Constructing Stoppings

(a) Non-Explosion Proof Stoppings

If a stopping is required simply to seal-off "Blackdamp" or an old section of the mine to prevent the inception of spontaneous heating, and when there is NO RISK OF AN EXPLOSION, then the stopping need only be AIRTIGHT; a brick or cement block wall about 0.5m thick, set back into the roof, sides and floor and sealed around its perimeter is sufficient. Timber, plywood and P.V.C. sheets or metal sheets would suffice as a temporary measure.

(b) Explosion Proof Stoppings

When stoppings are being constructed to contain and extinguish a fire there is always a risk of explosion and the stopping **MUST** be constructed accordingly. The decision to seal off by constructing stoppings should be made early enough to allow the stoppings to be completed before the fire reaches within 150m - 200m of the stopping sites and before an explosion occurs. Continual sampling and analysis will warn of the development of an explosive atmosphere. If that condition is approached before the stoppings are completed, then the work has to be abandoned with the hope that the unfinished stoppings will be capable of containing an explosion. The manner of constructing the stopping should keep in mind the possibility of being obliged to prematurely abandon the work.

When stoppings have been completed, the mine is totally evacuated, followed by a waiting period. The waiting period allows time for an explosion to take place or for a non-explosive atmosphere to develop. The end of the waiting period can be decided by:

- . the results of samples taken by remote sampling means.
- . the sound of an explosion or 'shock' on the stoppings - signalled to the surface via telephone lines connected to a suitable sensing device (such as a geophone).
- . the elapse of a prudent time interval (usually 24 hrs) followed by an inspection of the stopping site and sample taking.

Clearly the first two methods are to be preferred but, on occasion, the third option may be unavoidable. Following an explosion, there will be an examination of the stoppings. Invariably improvements to the strength and air tightness of the stopping are needed.

8.3.3 Design of Stoppings

a) Basic Structure and Fittings

- . Inside and outside walls across the roadway.
- . Access tubes.
- . Filling material between the two walls.
- . Reinforcing structures (not always used).
- . Sample pipes and instrumentation.

b) Walls

The purpose of the walls is to contain the filling material. The inner wall provides a bulkhead to contain fill material and to enable the "fill" to be packed against the roof. The wall should provide a seal against the roof, floor and sides, tight enough to prevent any liquid fill (such as cement grout or anhydrite) from leaking out before it sets.

The wall may be constructed from a wide range of materials including:

- . packed stones;
- . bricks or cement blocks; or
- . sand bags or rubble-filled wire net bags.

Before construction of the wall begins, all loose material must be removed from the floor, roof and sides and provision made for the wall to be keyed-in all around its perimeter.

Inside walls may also be constructed from a timber frame covered over with metal or plywood sheets with a plastic lining to prevent grout leakage. There is also a "Schwartz Arley Emergency Stopping" consisting of telescopic props, clips, hookbolts and galvanized pans. (See Figure 8.1).

These methods allow the fill to be placed while more durable materials are being brought on-site for the construction of the outer wall. In the interests of speed it might be necessary for the outer wall to be constructed in a manner similar to the inner wall. However, a final outer wall is usually constructed later when the immediate danger of fire and explosion has passed.

c) Access Tubes

In cases where it is intended, or possible, that the sealed-off area will be re-entered for recovery and/or salvage, steel access tubes are virtually essential to assure safe, quick and easy breaching of the stopping.

The "tube" (often a rectangular cross - section) consists of fabricated steel sections typically 61 cm in diameter; 1 m square or 2.5 m square. The minimum size should allow the passage of a person wearing a 2 hour breathing apparatus. The largest size "tubes" may allow the passage of a mine car or locomotive. Steel doors are fitted at each end. A typical explosion proof access tube is shown in figure 8.2.

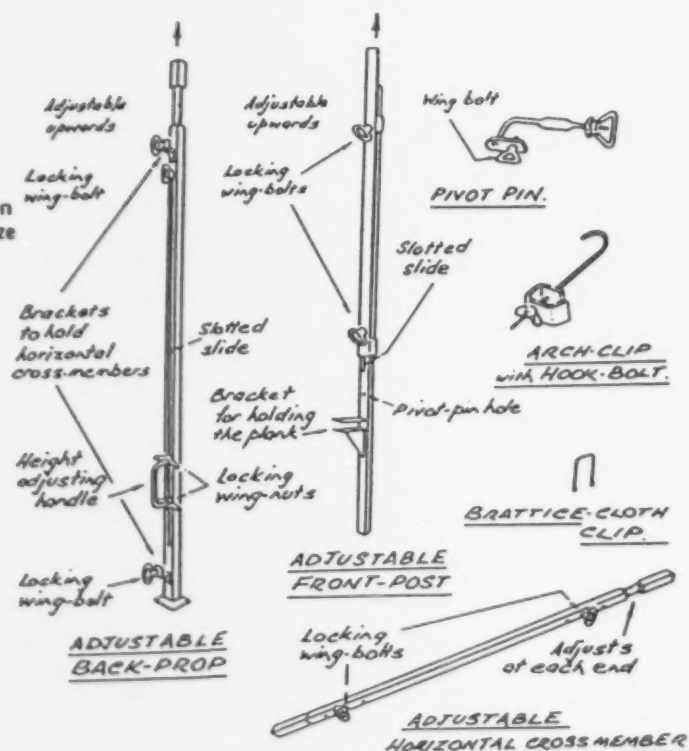
FIG. 8.1

The components of a typical
stopping consist of:

Adjustable back props	...	...	2
Adjustable horizontal cross members	...	...	2
Adjustable front posts	...	...	2
Archclip hook bolts	...	...	2
Pivot pins	...	...	2
Brattice cloth clips	...	...	Quantity of 20 plus
Teloscopic pans	...	...	Sufficient to fit the
			roadway cross section
			and of the correct size

Brattice cloth
Sandbags and or Hardstop bags

THE ARLEY EMERGENCY STOPPING ASSEMBLY COMPONENTS



Designed for use in roadways in excess of 8 feet high

ISOMETRIC VIEW OF EXPLOSION PROOF HARDSTOP STOPPING WITH SCHWARZ ARLEY WALLS

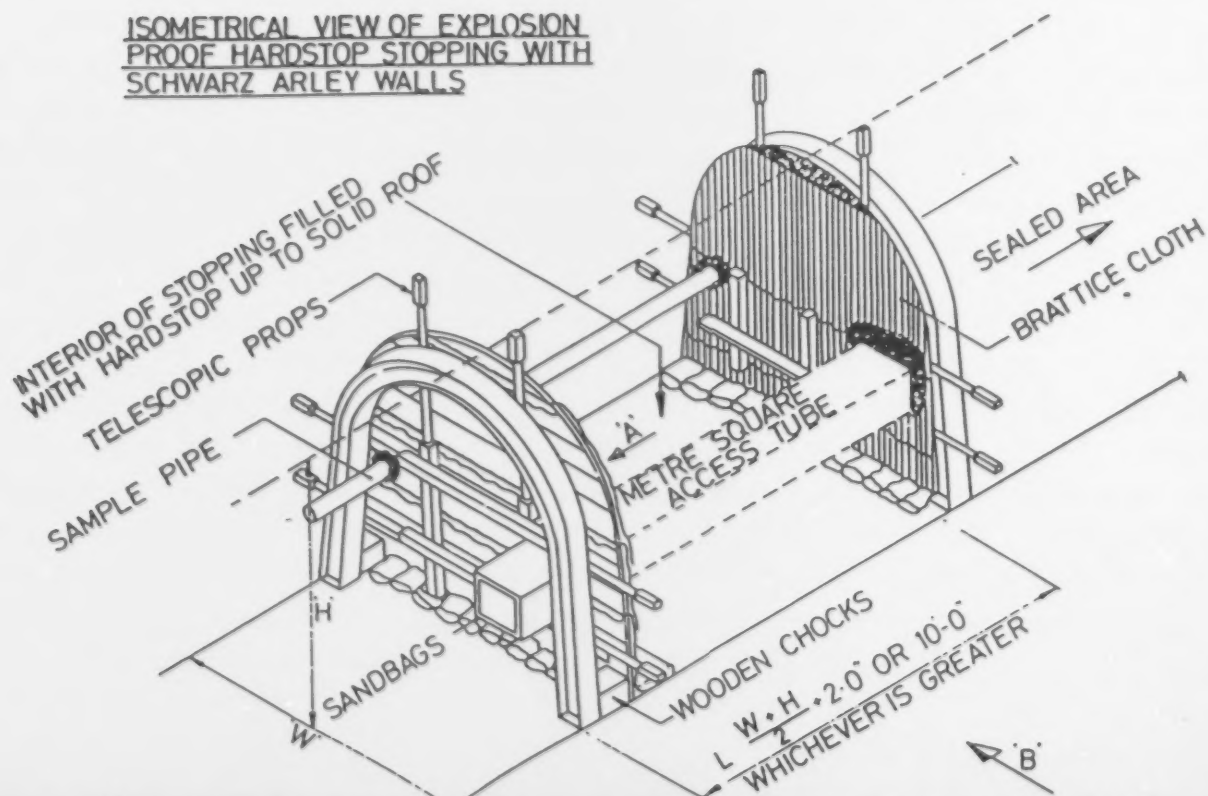
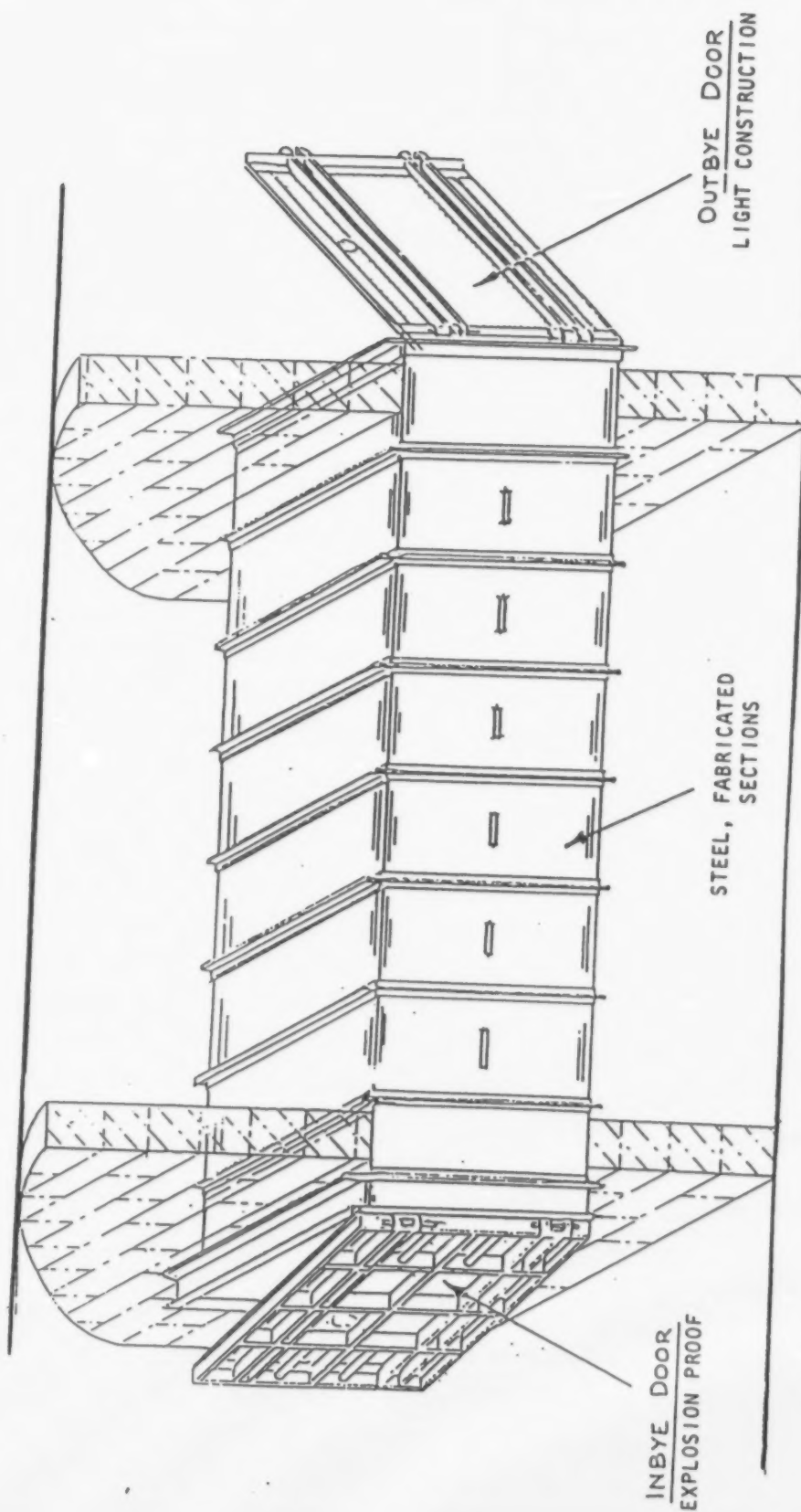


FIG. 3.2
EXPLOSION PROOF ACCESS TUBE



The tube is assembled, as the stopping is constructed, by adding sections. On completion of the stopping the "tube" extends just beyond the inner and outer walls. Its base is best positioned 0.5 m to 1.0 m above floor level at the outer wall and sloping downhill to the inner wall if possible.

If re-entry is not required, then the inner end of the tube is closed by an internal fitting door or plug and the tube filled with solid material - a ventilation duct can be used as an access tube for this purpose. If re-entry may be required, the heavier, fabricated, explosion proof, tube is installed complete with an explosion proof door at the inside end designed to withstand an applied "shock" pressure of 345 kPa (50 psi). The outer door is of light construction. The tube is not filled.

The purpose of the access tubes is to:

- . Provide access for recovery as previously mentioned;
- . Permit continued but controlled ventilation through the fire area while the stoppings are being constructed; and
- . To enable ventilation at all stopping sites to be closed-off at the same time by a synchronized closing of the doors.

The door should be fitted and tested for proper closing before the stopping is built around the "tube". Any difficulty and delay in closing at the right time could be very hazardous.

By allowing 30% to 50% of the normal ventilation to continue flowing through the access "tubes" it is possible to:

- . improve the working conditions at the inbye stopping, perhaps allowing the work to be done by "fresh-air" workers;
- . minimize the possibility of an explosion before the stopping is completed.

NOTE: The gradual restriction of the ventilation while completing a stopping without access tube, led to an explosion at Merlebach, France, in which 16 persons were killed; (Christmas Day 1976).

d) Filling Materials

Filling materials should be cheap, easily transported and, if pumped in, should set within 1/4 - 1 hour. Pit dirt is not a good material since it tends to settle and remain loose at roof level. If stoppings of this type fail after a heavy explosion, the top of the stopping is invariably blown away. Other common solid materials are sand/sand bags and boiler ash.

Materials which are pumped in are by far the best as the flow ensures that all breaks in the floor, sides and, with a little care, the roof are sealed.

Common materials are Gypsum, cement and sand grout, anhydrite and a range of propriety pump pack materials as well as crushed mine dirt suspended in gelling agents. The attraction of the pumping technique is that the pump can be located anywhere from 20 m to 2000 m away, sometimes at the surface. Good control and procedures are required to prevent "setting" in the pipe range; commercially supplied pump-pack materials do not set in the pipe - a considerable advantage.

Traditionally, when sand bags or mine dirt is used for fill, an explosion-proof stopping length is 8 to 10 metres. When monolithic pumped materials are used, the length is determined in the U.K. by the formula:

$$\text{Length (m)} = \frac{W + H}{2} + 0.6$$

where, W = maximum width (m)
H = maximum height (m)

The guideline formula used in coal mines of the F.R. of Germany is:

$$\text{Length (m)} = 0.865 \times a \times \frac{q}{b}^{1/2}$$

where, a = maximum width or height (whichever is greater
after lagging has been removed)
q = static explosion pressure (N/mm²)
b = bending or tensile strength of fill material
(N/mm²)

This German formula provides a shorter length for an explosion-proof stopping than the British. To the best of the consultants knowledge no guidelines have been given in any Canadian province.

e) Re-Enforcing Structures

Re-enforcing structures consist of steel girders placed obliquely across the roadway being filled. The outer end of the girder may be pocketed into the side or floor of the roadway. Re-enforcing has been used where the stopping fill material consisted of sand bags or mine debris and sand. When monolithic materials are used, re-enforcing is unnecessary.

f) Sample Pipes and Instrumentation

Sample Pipes: These must always be included in the construction of every stopping. Their inbye end is secured about 10 m beyond the stopping about 1 m below the roof. The outbye end is placed at a convenient height for sampling or it is coupled to a tube-bundle sampling system. The tube should be marked and tested after installation.

Temperature Probe: It is often useful to monitor the temperature trend behind a stopping to gain an indication of fire decline or re-entry conditions for rescue men.

Gas and Water Ranges: 150 mm diameter pipe lengths should be installed through stoppings at roof and floor levels for future drainage of gas and/or water.

Where methane drainage pipes are in place they should be allowed to remain. It is beneficial to continue the operation of vacuum pumps to remove methane while the stopping is being constructed. When the stopping is completed, methane drainage should be discontinued to allow an extinctive atmosphere to develop more quickly.

All pipes through the stopping must be fitted with suitable valves; "Butterfly" type valves are not suitable.

Communications: Communications between the stopping and surface control are important during a sealing operation and are vital between the stopping site and the filling material mixing and pumping station. Telephones with loud speaker systems are recommended. Rescue men in breathing apparatus should establish

a code of signals to be used with the pumping station, for example:

- . "stop pumping"..... 1
- . "start pumping"..... 2
- . "flush out"..... 3
- . "mix too thick"..... 4
- . "mix too thin"..... 5

g) Construction Procedures

Construction requires mainly hard work and, in the interests of speed, needs plenty of manpower so that crews can be rotated to maintain a continuous high output level.

The first, inside, wall should receive special attention to ensure that:

- . it will not give way under the load of fill to be placed against it;
- . it is as leak proof as possible.

While the inner wall is under construction the pipes, fittings and access tube must arrive at site as early as possible, especially the first 2-3 sections of the access tube. In addition, the fill materials and (if they are to be used) the pump pack apparatus should be prepared and tested. The area inside the stopping should be liberally rock dusted if there is time and labour available. The supply of fill materials should enable the filling to go from start to finish without interruption; stopping and starting gypsum and anhydride equipment may lead to problems such as blocked pipes.

Estimates of fill quantities can be based on:

1 tonne of material to each m^3 to be filled + 10%

The extra 10% provides for leaks and losses.

As the fill is being placed, the principal supports are left in-situ (i.e., steel arches, props and beams or collars across the roadway). However, covering material and lagging is removed systematically as filling proceeds. This allows the fill to seal up to the sides of the roadway. If covering is left in place it is nearly impossible to ensure that all the voids have been filled and that there will be no leakage around the perimeter of the stopping.

The pumping operation is routine except for the last 1.0 m up to the roof. To get a good seal at the top of a stopping is difficult and time consuming, usually because of fill leakage at the tops of the inner and outer walls; sometimes as much as 20t can be lost due to leakage. The access tube is then invaluable since it provides an access to the inside of the inner wall enabling leaks to be plugged.

It may take only 6-10 hours to fill a stopping to within a metre of the roof, using 6 t/hr capacity equipment, but it may take another 6 hours to "top-off" and make the stopping solid.

Further information on the design of stoppings can be obtained from a CANMET, Division (draft) Report from Cape Breton Coal Research Laboratory, August 1988", Technical Note on the Construction of Stoppings or Dams in the Sydney Coalfield", by G.A. Haslett.

8.3.4 Working Conditions at Stoppings

a) Ventilation

A number of stoppings may be needed to seal off a fire, almost always at least two. Stoppings must be constructed on the intake and the return sides. The intake side is less of a problem and the work can often be done by "fresh-air" men.

The return side can be very difficult due to heat, humidity, smoke and toxic fumes and the work must often be done by Rescue Teams in breathing apparatus. Occasionally, where the stopping is high and the smoke and fumes are at roof level, Rescue Teams might work at the top of the stopping and "fresh-air" men at the bottom. However, in all cases, the respective tasks of the two groups must be clearly defined and adhered to rigidly. Standby rescue teams are required nearby to safeguard both rescue team workers and "fresh-air" men.

The stoppings will be constructed, ideally, close to an intake - return cross-out. The air flow close to the stopping construction sites can be improved by temporarily opening doors or regulators in the cross-cut.

This lowers the ventilating pressure drop across the fire-affected district, provides positive ventilation flows for the staff working on the stoppings and takes a good supply of fresh air as near as possible to the men working on the return stopping.

At the return stopping (or return side of a fire) conditions can be very unpleasant for the teams at work. The air may be hot, smokey and toxic with high velocities in the access tube.

It may be necessary to create tolerable conditions at the return stopping sites by using auxiliary fans and ducts or line brattices. The fans can force cooling fresh air to the site. Ducts, with or without fans may be used to pass smoke and hot fumes issuing from an access tube, directly to a main return. It is important that rescue teams and firefighters are well trained, in simulated conditions, to work in a hot, smoke filled atmosphere where visibility is almost nil. Once all seals have been completed, the inside doors of the access tubes are closed simultaneously. When the access tubes have been vacated, the outer door is closed.

After adjustments to the ventilation all men are withdrawn from the mine until the explosion risk is passed - normally a period of 12 to 24 hours is sufficient. After an explosion has occurred, secondary or even repeated explosions are not uncommon.

b) Clothing for Fire-Fighters

It should be remembered that in fighting a mine fire, rescue men and firefighters may be subject to flame or burning materials e.g., "flash-overs" of burning methane or minor falls of hot-material from the roof. It is hardly appropriate for them to be wearing normal mine work garments and the availability of special fire resistant clothing for this situation is recommended.

Persons who have been engaged in firefighting or building stoppings are likely to be soaked with water. Wet suits should be available at the mine, reserved specially for firefighting but, more importantly, an adequate supply of blankets and dry clothing should be taken underground so that soaked workers can change and keep warm while riding out of the mine on man-rakes travelling against the cold intake air.

8.3.5 Pressure Balancing Chambers

As soon as the immediate emergency is over and the stoppings have been examined, it is usually necessary to improve the sealing around the stopping and take steps to prevent leakage into (or out of) the enclosed fire area. One way of doing this is by balancing and equalizing the pressures on the faces of the stoppings. This is done by erecting a second, sealed wall to create an air-tight chamber across the faces of the stoppings. Access to the chamber is by means of air-tight air-lock doors. The pressure in each of these chambers is equalized, maintaining the pressure differential across all the stoppings, so far as practicable, at zero.

To maintain good leakage control, the pressure differences between each of the main pressure balancing chambers should never exceed 2Pa (0.2 mm W.G.). This can be achieved using automatic, sensitive, pressure controllers (Bibliography Ref. 52).

Some authorities recommend that the required pressure levels in the pressure balancing chambers should be obtained from the mine ventilation system using 300 mm diameter ducts (12 in. diameter) passing into the chamber in preference to the use of fans, blowers, venturis, air movers etc.

Large and abrupt changes in barometric pressure require that one of the stoppings (preferably one near to a main return) is allowed to function as a "spill-over" from which gas emissions (containing blackdamp, methane and CO) MAY occur from time to time. Provision should be made for this to take place safely.

It is often considered good practice to drain methane from sealed areas - usually from a return side stopping, and pass it into an existing methane drainage system. The available volume of methane and its purity will vary according to barometric pressures therefore flow control is required. A simple and effective purity control system is available, which automatically opens and closes the methane range valve according to the purity of the methane.

More information on the application, construction and control of leakage of stoppings is given in references listed in the Bibliography.

8.3.6 Other Methods of Stopping-off Fires

a) Water Seals

Where the gradients of a mine permit, it is sometimes possible to simply pump water into a roadway to form an effective seal very quickly.

An obvious example is to flood a fire at the face of a downslope heading. Another possibility might be to flood a roadway where it passes through a depression. In this case, to be successful, the water plug should be up to the roof level for a distance of at least 5 m and the time required to fill the roadway

depression should not be more than it would take to build a stopping.

b) Boreholes

Boreholes from the surface, or from another section of the mine (such as an upper seam) may be used to deposit water, grout, inert gas, fly ash/cement etc. into a roadway to form a plug or fire seal.

Drilling time (including moving a rig on-site and setting-up; the need for accurate directional drilling; and the ability to pinpoint the drilling target are all important considerations when deciding whether boreholes can be of help.

c) The Filling of Shafts or Drifts Against a Fire

These are "last step" methods. The large volumes of material required must be moved by machines, and heavy work is required to strip the shaft or drifts of services such as guide ropes, conveyors etc. It is still important to leave in sampling pipes.

All accesses to the surface may need sealing including broken ground, and grouting may be necessary. The sealing operations may cause pollution problems. The recovery of a mine sealed in this way is very complicated and costly; once done it is usually the end of the mine unless there are extensive valuable reserves remaining to justify re-opening or the development of new accesses.

9.0 MINE VENTILATION AND FIRES

9.1 INTRODUCTORY COMMENTS

Ventilation plays a major role in the events surrounding a fire incident, for example:

- . coursing of smoke and fumes in the mine;
- . the safe evacuation of workers from affected areas of the mine;
- . the progress of the fire,
- . the supply of air to maintain burning;
- . the presence of methane;
- . high temperatures downwind of the fire.
- . derangements of the normal ventilation, caused by the fire;
- . control of the fire by changes made to the ventilation; and
- . reduction of hazard by changes made to the ventilation.

Many aspects of ventilation and fires are well documented, and were also dealt with at length at the seminar held in Sydney, Nova Scotia on 17th September 1984 under the title "Underground Coal Mine Fire Control". Coal Mine Management; Safety, Fire Prevention and Ventilation Officials, attended the seminar, as did Trade Unions representatives, Mine Inspectors and CANMET personnel. Each member received copies of the technical papers presented at the proceedings.

It is important that, during a fire incident, persons with special knowledge of ventilation are included in the "Incident Control" team. A person who is to be nominated to this position should be well informed as to the phenomena associated with fires and ventilation and be well versed in the interpretation of mine fire atmospheres and the application of ventilation adjustments to assist fire control.

9.2 THE THERMAL EFFECTS

9.2.1 Buoyancy

The heated air from a fire, being less dense than the cool air entering a mine, may generate convection flows due to the buoyancy of the hot air. This effect takes place where there are inclined roadways and shafts. It may occur locally in the form of limited re-circulation or it may, in severe cases, affect the ventilation of the whole mine.

In the CBDC mines of the Sydney coalfield, the thermal effects of a mine fire are potentially severe due to the steepness and length of the main access roadways from the surface.

a) Hot Air in the Main Return Slopes

A body of hot (or even warm) air entering the bottom of the return slopes, as it could from a fire in almost any part of the mine, would increase the effective ventilating pressure. Increasing volumes of air would be induced to flow, at increasing velocities. An uphill, hot return would act like a chimney producing ever-increasing velocities in the main intakes and returns until a state of equilibrium was reached. Clearly action is required without delay to arrest this process.

b) Hot Air in Main Intake Slopes

If a fire was to occur in the main intake (for example, a fire on a conveyor) the hot air and fumes from the fire would decrease the effective ventilating pressure because the uphill buoyancy of the hot air would oppose the downhill intake air flow and the ventilation flow would decrease. This could have a number of effects, depending on the size of the fire and its location down the slope. For example:

- . diminished air flow at the fire which could slow its progress and intensity;
- . the build-up of explosive concentrations of methane; and
- . reversals of the normal air flow.

9.2.2 Determination of Thermal Effects

Quantitatively, thermal ventilating pressures can be deduced from charts similar to that shown in Figure 9.1. However, it is apparent from these charts that accurate knowledge of the fire location as well as air temperatures are very important for accurate forecasts to be made. Nevertheless, a good knowledge of mine ventilation and local mine conditions should allow "common-sense" qualitative analyses to be made.

It should be remembered that:

- . A fire near the face of downhill heading can set up a recirculation current in addition to the ducted auxiliary ventilation, see figure 9.2.
- . An intense fire near the bottom of an uphill return slope can cause doors separating intake and return, up-slope of the fire, to be drawn open allowing recirculation to take place, see figure 9.3.
- . Thermal effects are most severe in shafts and long, steep slopes. It is not impossible for air to be drawn in reverse through main fans and possibly booster fans.

(See "Influence of Mine Fires on the Ventilation of Underground Mines", Rudolf E. Grever, USBM Contract Report No. S0122095, 1973).

A. Ralph, R.W. Upfold, M.D. Velzeboer

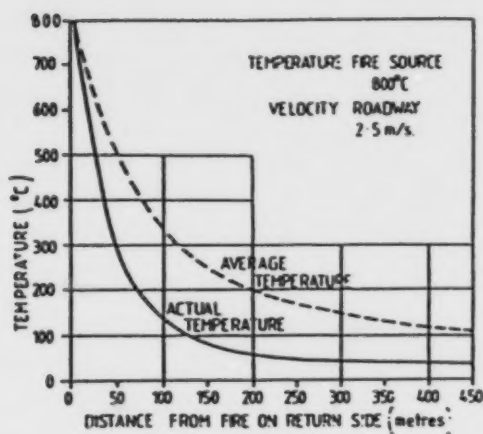


FIGURE 1
ACTUAL AND AVERAGE AIR TEMPERATURES
BEHIND AN U.GROUND FIRE (AFTER SCHUBERT
AND BOTH)

Figure 1 shows the temperature distribution along a single roadway for a 800°C heat source fire as reported by Schubert and Both (1974)(8). Figure 2 illustrates the buoyancy effect of the same fire source related to air column height available using the following relationship :

$$p = (b \times h \times (tm - ti)) \div (r(ti + 273) \times (tm + 273))$$

where b = absolute air pressure (K)
 h = effective difference in elevation (m)
 tm = average temperature in °C on return side of the fire
 ti = intake air temperature in °C
 r = universal gas constant

From this relationship the significance of an accurate knowledge of the fire source temperature and the temperature gradient along the roadway becomes readily apparent.

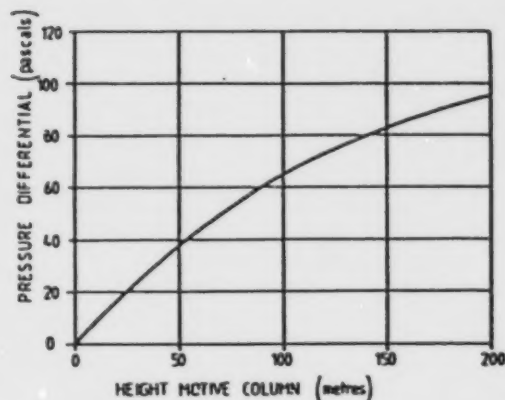


FIGURE 2
PRESSURE DIFFERENTIAL OF MOTIVE COLUMN
DUE TO AN U.GROUND FIRE (AFTER SCHUBERT
AND BOTH)

VENTILATION INSTABILITY Ascensional Ventilation

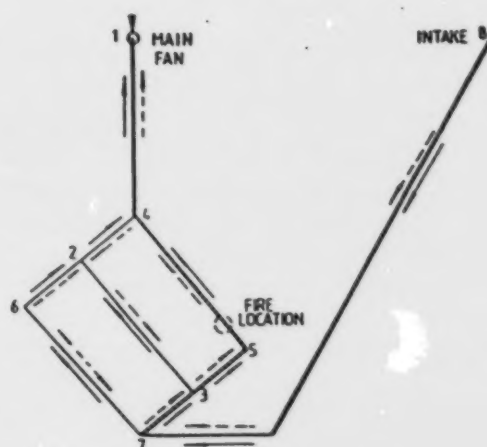
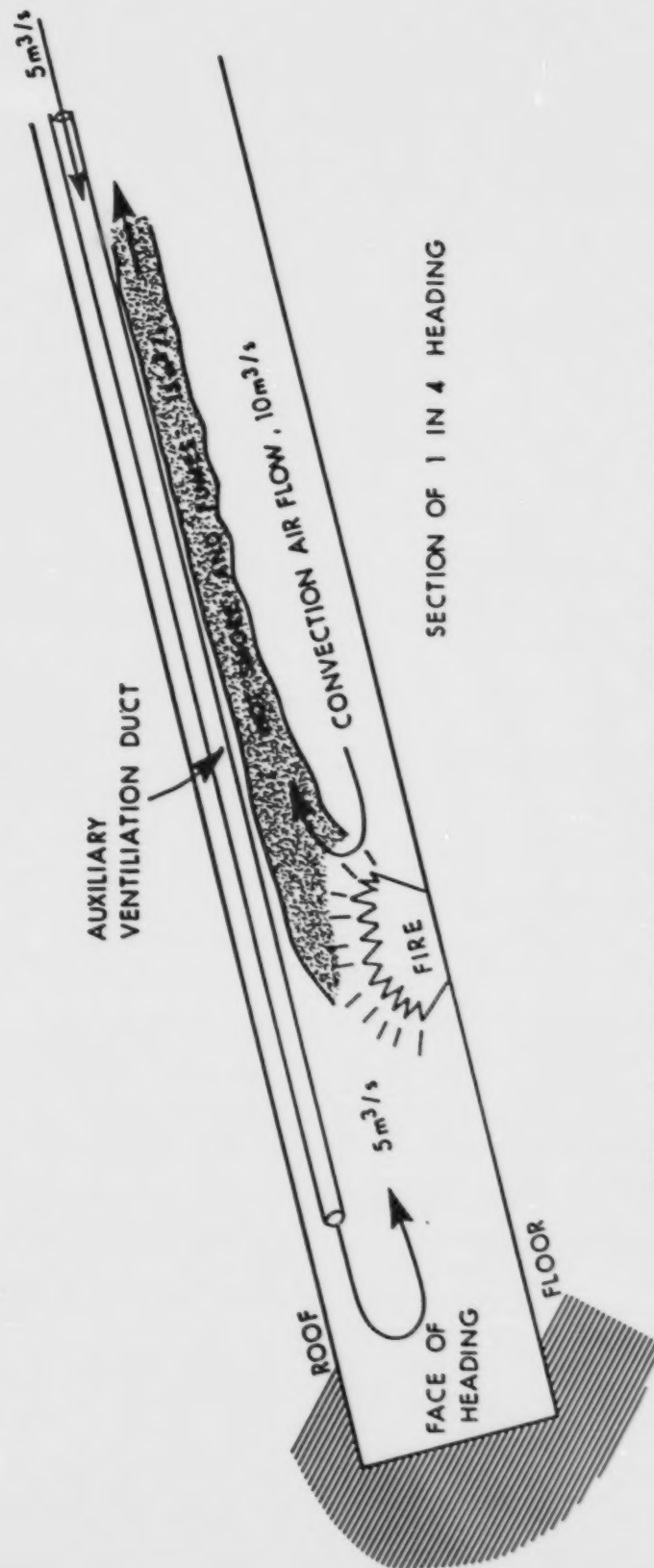


FIGURE 3
STABILITY OF AIRFLOW WITH AN UNDERGROUND FIRE
ASCENSIONAL VENTILATION

5 — NODE LOCATION
 — FLOW DIRECTION BEFORE FIRE
 - - - FLOW DIRECTION BECAUSE OF FIRE
 — STABLE AIRWAYS

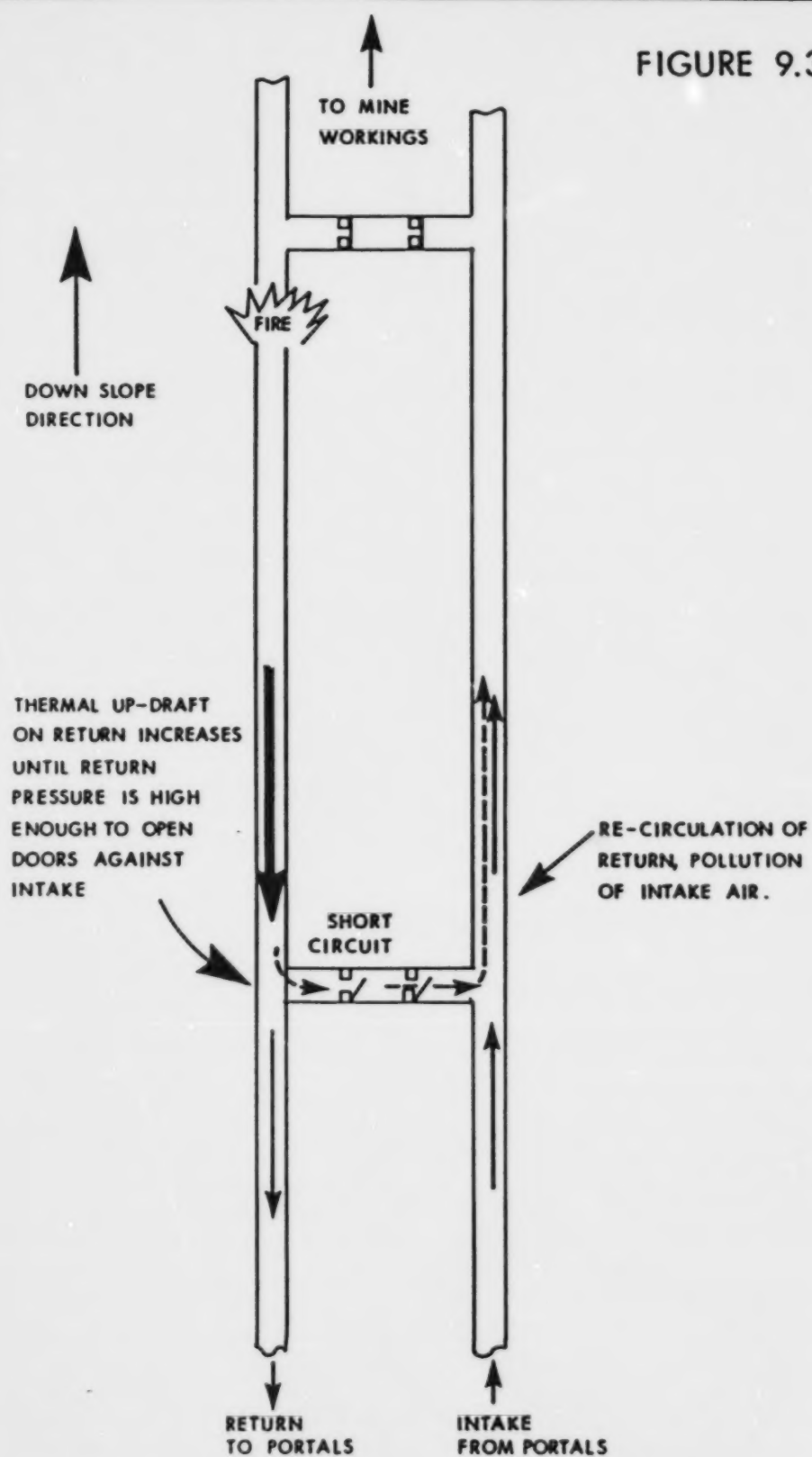
FIGURE 9-2



SECTION OF 1 IN 4 HEADING

FIRE AT THE FACE OF A DOWNHILL HEADING
(Example of an occurrence in a Lancashire, U.K. Mine)

FIGURE 9.3



FIRE NEAR BOTTOM OF UP-HILL RETURN

9.2.3 Thermal Constriction

If the volume of return air is increased due to heat then velocities - and consequently velocity pressures - will increase. This, in effect results in an increased ventilation resistance. The phenomenon is referred to as "Thermal Constriction". It may unbalance the normal air flow in "splits" ventilated in parallel with the split where a fire is in progress.

9.3 CHANGING THE VENTILATION

9.3.1 Changes While Combatting a Fire

After an explosion, an ignition of methane or during a fire any ill-considered changes to the ventilation can produce disastrous results. Changes to the ventilation are often required to control a fire but they should only be attempted after the overall situation has been carefully appraised and the implications of the change competently assessed. In an emergency, a mine official on the spot might take immediate action on a very local scale to mitigate the effects of a fire, providing the action has been carefully considered. Such action should not involve major changes affecting other sections of the mine and the action taken should be reported to the Control Centre as soon as possible.

9.3.2 Potentially Hazardous Changes

Unauthorized, major changes to the ventilation, such as opening doors, regulators, breaking through stoppings, taking down brattices, installing temporary regulators and stopping or starting booster fans, can produce some very hazardous conditions no matter how well intentioned the action was.

Actions taken to increase the ventilation in one area, in order to dissipate gas and smoke, may result in feeding more air, and possibly methane too, onto a fire and increasing the rate of fire progress. Reducing the air flow in order to reduce the rate at which smoke issues from a panel returns into a main return, may produce a methane build-up to explosive concentrations and cause smoke and heat to back-up over fire fighters tackling the fire from the intake side.

It is extremely difficult to foresee the results of ventilation changes, even for those in the relative calm of a control room, equipped with ventilation plans, knowledgeable advisors and reports from different sections of the mine. It is virtually impossible for someone in the mine, without this information to make major changes in an informed manner.

9.3.3 Strategic Changes

Once reliable information is being received at the control centre as a result of reports from the fire-site, from airways inspections, main fan inspections and air analyses, then the person-in-charge and his technical advisors are able to contemplate any benefits that might be gained from changes to the ventilation. These benefits might include:

- . reducing the rate of progress of the fire;
- . reducing the spread of smoke; and
- . clearing smoke from certain roadways to allow persons to exit the mine safely and allow transport systems to be used.

Reducing the air speed over a fire can play a major role in helping bring the fire under control by reducing the rate of travel of the fire, the intensity of the fire and consequently the volume of smoke and fumes produced. Experience at actual fires and in experiments has shown that, at air speeds of 3-4 m³/s, a fuel rich fire, burning timber and lagging, will progress at speeds up to 20 m/hr and the fumes will include:

- . carbon monoxide, 0.1 - 1.0%
- . carbon dioxide, 2.5 - 7.0%
- . oxygen, 14.0 - 18.5%

However, small scale tests in a duct, burning wood, showed that fire progress is directly proportional to air speed. (Roberts and Blackwell 1969).

a) Restricting or Stopping Ventilation

This can be achieved locally by:

- . Regulating a short circuit between intake and return so as to reduce the flow through the split where a fire is in progress.
- . By erecting brattices across the intake to a fire or the return from a fire. The latter would probably have to be done in smoke.

Slowing, restricting or stopping the main fan, or opening the main fan air-lock are means for reducing the total air flow in the whole mine. The main disadvantages of these measures are:

- . By excessive restriction of air entering the fan, the fan may be caused to operate under "stall" conditions and be severely damaged.

- . Natural and thermal ventilation may take over in parts of the mine or even throughout the whole mine.
- . It may be difficult (perhaps impossible) to return the fan to normal operation and return to the original conditions; in short, there could be total loss of ventilation control.

These measures must be regarded as "last resort".

9.3.4 Reversing the Air at the Main Fan

a) Centrifugal Fan

If the fan is a centrifugal fan, the air flow is reversed by opening and closing steel doors at the fan installation; the rotation of the fan is unchanged. However, the fan is not running under its designed conditions and therefore there will be some reduction in performance.

b) Axial Flow Fan

Reversing the rotation of an axial flow fan would normally reverse the air flow but the fan installation would operate at such a reduced capacity that reversal of rotation may not in fact, effectively reverse the air flow.

c) Ventilating Doors

Most ventilation doors are built to be held closed by the normal ventilating pressure. On reversing the air, many of these doors would blow open and the main intakes and returns would be short circuited.

d) Considerations for Reversal

The only condition, in an underground mine, where reversal of the mine's ventilation might be quickly considered, would be where a fire had broken out at the top of a main intake airway. The objective would be to reduce the risk of smoke and noxious fumes being carried into the working areas.

Even this situation would require only a short time in the reversed condition; just enough to permit a very rapid attack on the fire from the fresh air side.

Evacuation of the mine by all personnel not actively engaged in the fire-fighting, would proceed simultaneously.

In the case of all other hazardous situations, or in the event of a major incident underground, the potential dangers resulting from reversal of the fan would be very carefully weighed before the decision were made.

In summary:

- . fan reversal is a decision which is never lightly taken;
- . the dangers of methane concentrations reaching the explosive range very real;
- . the dangers of creating un-ventilated zones due to short circuiting of the air current are very high; and
- . where normal ventilation direction can be maintained, in the majority of cases, this is the safest way to proceed.

9.3.5 Localized Reversal of the Air

This can be a very useful device where conditions and mine layout permit its use.

In the CBDC mines, the main conveyor slopes are intakes and have been recognized as a fire risk area from which smoke and fumes would be carried into the working sections of the mine. To combat this, plans have been devised for reversing the ventilation locally in these slopes without incurring a general reversal of the air. This can be accomplished because of having multiple intakes and return slopes. The air flow is reversed by:

- . opening doors between one of the main intakes and the conveyor intake, down slope of the fire;
- . opening a door between the conveyor intake and the main return close to the main, exhausting fan outlet; and
- . placing a temporary stopping in the main conveyor intake, above the connection to the return. This temporary stopping can be just inside the portal.

At the outbreak of fire in the conveyor road, these adjustments will cause air from the adjacent intake to enter the conveyor road and flow up hill, past the fire, through the opened door into the return and out of the mine via the fan. The temporary stopping minimizes the effect of a short circuit and should be already in place when the door to the return is opened.

This system has been tried at the Langan Mine and operated successfully. It is worth noting that the thermal effect of a conveyor road fire would be in favour of the reversed flow. The main problem would be the use of an inflatable seal as a temporary stopping. The reversal, ideally, should be done

quickly; it would take too long to place an inflatable seal in position and inflate it. (See Section 9.4 dealing with inflatable stoppings). It is recommended that a system be developed that can:

- . stop-off the conveyor road by means of doors in place of an inflatable seal; and
- . operate all the doors for implementing the reversal system by remote means from the mine's central control.

Remote operation of the reversal system will assume greater importance when the plans to operate the conveyors on remote control are implemented. When this is done it may prove impossible to be assured that there is someone available to manually open the doors in an emergency.

The cost of installing a remotely operated air reversal system is estimated to be in the region of \$200,000 per mine.

In spite of this cost, it is suggested that the benefits would be considerable, particularly in terms of speed and reliability in an emergency. The reversal procedure should not take more than 10 minutes.

9.4 INFLATABLE TEMPORARY STOPPINGS

9.4.1 Description

Inflatable stoppings are essentially air bags made from flexible, flame resistant materials such as PVC coated nylon or neoprene plys. They are usually available in different grades of material toughness but if they are to inflate against rough walls and sharp edges, the toughest material is desirable. Valves and fittings are provided to enable the bag to be air-filled from the compressed air supply and they are provided with

"D"-rings and loops for handling and mooring. There is usually a safety relief valve to prevent over-inflation. They are available in a variety of shapes and sizes and may comprise a number of cylindrical air bags which can be arranged in a parallel manner to occupy a variety of roadway shapes. Some manufacturers incorporate zip fastener doors to provide access through the stopping.

9.4.2 Handling

Care must be taken when handling, transporting and inflating. The air bag material is tough but can be punctured if not handled with care. The larger deflated bags are heavy and bulky to move and require a transport system e.g., a mine car or flat wagon to get them on site. They should not be over-inflated and the use of a pressure gauge is recommended. Inflated pressure is around 1 kPa (= 0.145 psi = 4 in W.G.).

Some site preparation is required prior to inflation. Sharp protrusions from the roadway perimeter should be removed or padded. Conveyor structure should be removed and the belting allowed to sag to the floor. Pipes and cables are a problem unless they are tight to the roof or sides.

As the stopping is being inflated to fill the roadway, its mooring lines should be attached to the provided "D-rings" and anchored securely to fixtures in the roadway. As the bag expands to fill the roadway the ventilating pressure against the seal can create a force as much as 500 kg (1/2 tonne). The mooring lines will prevent the seal from being moved out of the required position and will safeguard those erecting the seal.

9.4.3 Application

There is a practical limit to the size of bag which can be manufactured and used. They are not suitable for roadways larger than about 12 m² (120 ft.²). A roadway is rarely well sealed by an inflatable stopping. In effect they act like regulators. Even when correctly inflated they are very leaky. Tests have shown that, on average, the normal air flow is reduced by 80%. The leakage occurs round the sides and top of the stopping and around obstructions such as supports, cables and pipes.

Inflatable seals can be used to regulate air flows in fire areas and to protect fire fighters from smoke until a more permanent barrier can be constructed. They are unsuitable as protection against flame or very hot fumes. Their structure is too light and flexible for them to be employed as a quick inner wall structure for building an explosion proof stopping.

In summary, inflatable stoppings have very limited application and in many cases a telescopic frame type structure is less costly and as quick to install. Nevertheless it is useful to have one or two on hand for special circumstances.

9.5 RETREATING PANEL BLEEDER SYSTEMS

9.5.1 Need for Bleeder Systems

The Bleeder System is necessary in the present Sydney Coalfield conditions. By keeping the methane fringe back in the gob, away from electrical equipment and moving machinery at the top end of the retreating wall, the risk of a methane ignition can be avoided; the Phalen No. 1 East Bleeder System successfully does this.

As more, high production, retreat walls are developed, bleeder systems will be essential for ignition-free face operations. Panel conditions and mine ventilation circuits are constantly changing and Bleeder System performances should be carefully monitored.

9.5.2 Areas of Concern

The application of retreating panel Bleeder Systems in the Sydney coalfield is relatively new. Mine planning and engineering should consider the following areas of concern.

(a) Limits of Gob Ventilation

The air migration from the face back through the gob is limited by:

- . the Ventilating pressure drop between the face and the "Back Bleeder"
- . the resistance of the gob, (i.e. the degree of gob consolidation)

In the case of Phalen's No. 1 East Panel, the resistance is low enough that there is sufficient flow to keep methane back from the face. The triangular space along the pillar edge at the top of the panel undoubtedly helps create a relatively low resistance. This might change if a different type of arch is used (as is planned). As the face retreats the resistance of the path through the gob will increase; if a stage is reached when the flow is inadequate, it can be restored by breaking the seal in a cross-cut behind the face line to shorten the leakage path into the bleeder entry.

The projected layout of the No. 2 East Panel will not have this facility, since there are no cross-cuts and no bleeder road in the pillar separating the No. 1 and No. 2 East Panels. It has not yet been established that adequate air leakage through the gob can be maintained for distances of almost 2,400 m and it may not be possible to keep the top end of No. 2 East wall clear of methane unless the Top Entry is maintained as an accessible entry.

(b) Methane Drainage

In the projected layout for No. 2 East Panel, if the Top and Bottom entries are allowed to collapse as the face retreats, no bleeder road will remain open. It will then not be possible to introduce methane drainage from boreholes over the gob (in addition to air leakage through the gob) as a means of controlling methane concentrations on the wall.

The No. 1 East retreat panel operates satisfactorily without drainage from boreholes but, with increased depth and higher production levels, supplementary drainage from boreholes may become necessary. Panel layout and operation should provide for an airway to be maintained behind the face. (Ref.: Highton W.; Browning E.J., 1988 "Environmental Control and Design for the Future". - The Mining Engineer, Vol. 148, No. 322, July 1988).

(c) Hanging Fire in Gobs

The atmosphere at the gob edge of a retreating panel will normally be free of methane. However, at the outflow of gob bleeders the methane content may be above 40%. The leakage air through the gob will hold a methane "fringe" back in the gob, away from the face but there will be zones in the gob where the

methane content is in the flammable/explosive range, that is, roughly, between 5% and 15% methane.

The collapse of Sandstone rock in the gob and the buckling and crushing of steel supports and metal backing sheets along the gob edges, are two possible sources of methane ignition from frictional sparking.

A methane ignition in the gob could result in a "hanging fire" of ignited methane continuously burning for days. This would produce large volumes of carbon dioxide and carbon monoxide and may result in an explosion.

The existence of a hanging fire would no doubt be detected by monitoring the presence of carbon dioxide and monoxide on the bleeder outlet.

The question then arises of how to extinguish a "hanging fire" in the gob. The introduction of a cooling, water mist or fine stone dust, into the air flowing through the gob might be tried as a relatively inexpensive method. The use of inert gases would be more effective but expensive.

It is probable that stoppings would have to be erected and nitrogen pumped in behind them. However, once the stoppings were in place, the mine could resume operations. It is likely that burning gas could be extinguished rapidly without the face suffering major damage. Clearly the fire would have to be extinguished and if the face and equipment could be preserved, the cost of nitrogen would easily be justified.

9.5.3 Air Flow Patterns in Gobs

The migration of methane, the leakage flow paths through the gob, the inclination and general layout of the panel, are factors which influence the above mentioned areas of concern. It is suggested that these factors and their interaction may be a subject for further investigation and that a physical model might be used to facilitate flow pattern studies.

9.6 EXPLOSIVE AND EXTINGUISHING ATMOSPHERES

9.6.1 Gases

Under most circumstances air is present in mine atmospheres in varying amounts; this means there is usually some oxygen and always Nitrogen, present. The fire itself generates carbon dioxide, carbon monoxide and hydrogen, the last two being flammable. In air, CO is flammable between 15 and 74% and, also in air; H₂ is flammable between 4 and 75%.

Hydrogen is so flammable that it will burn in atmospheres containing as little as 5% O₂.

Methane is always dangerous, being flammable in air from 5 to 15% approx. During fire fighting, sealing-off, inerting and recovery operations, the continuous changes in mine atmospheres are extremely important. The rapid analyses of atmosphere samples are essential in assessing:

- . the progress and intensity of a fire.
- . the development of an explosive atmosphere while sealing-off.
- . the development of an extinguishing atmosphere after sealing-off or during inerting.
- . the progress of a fire towards its extinction.

9.6.2 Collection of Samples

The existing instrumentation in the CBDC mines is an obvious source of continual monitoring through remote sensors with the information collected and recorded through the mines' remote monitoring and control system. However, in the event of a fire, it is likely that the sensors nearest the fire, on the downwind side, will be damaged or be unreliable. Each sensor is only capable of one detection function, air flow, methane, CO or smoke detection being the most common. It would be useful in case of fire if CO₂ and O₂ sensors were also in operation.

In the course of a fire containment operation three types of sampling are possible:

- . direct reading of hand held devices such as Methane/O₂ instruments and "Drager tubes".
- . manual collection of samples by means of sample bottles and/or evacuated flasks.
- . continuous remote sampling via 'tube bundles' in which samples are drawn through small diameter plastic pipes from a number of locations.

The manual and tube bundle remote sampling methods require analysis to produce useful data.

9.6.3 Analyses of Samples

During a fire related incident, rapid, accurate analysis of a large number of samples, is required for a period that might extend more than three to four weeks.

Rapid analysis is essential to be able to quickly assess the effectiveness of actions taken and to reduce the risk of fire fighters being involved in an explosion of gases. Mobile laboratory services equipped with high speed gas analysis equipment is provided in some European countries (i.e. U.K.). It is recommended that CBDC review the present facilities for both sampling and analysis with a view to speeding up these operations.

9.6.4 Interpretation of Results

The results of sample analyses are used to trace the trend of changing atmospheres into or away from an explosive range. This is done by plotting the results on a classic 'Coward Triangle' chart appropriate to the particular circumstances. To be effective, a range of charts is required which cover a wide variety of gas mixtures whose explosibility depends on

the percentage of oxygen present as well as on the presence of "fuel" gases such as CO, hydrogen, methane and other hydrocarbon gases.

9.7 APPLICATION OF COMPUTERS

9.7.1 Prediction of Effects of Fire on Ventilation

Numerical methods of prediction have been reported (USBM Report No. S0122095-Grever) but the process is laborious and too slow to be of practical value in an emergency. Computer programs are available which could be useful in analyzing hypothetical fire conditions as an aid to pre-preparation strategy. However, in an actual incident, the ability to acquire input data at a level of accuracy and detail sufficient to produce reliable results is questionable. There is a danger that, where long, steeply inclined roadways are involved, a small error in temperature

estimation would produce a misleading interpretation. In most fire cases there has been sufficient information available for a practical qualitative analysis to be made. Qualitative analysis may also be aided by the use of physical models and this technique has been employed in the U.K. The ventilation systems of the CBDC mines are not complex and models may be very useful.

Quantitative results, when conditions are changing rapidly, are likely to be questionable and therefore unusable.

9.7.2 Determination of Explosibility

Graphical methods of determining explosibility were developed by Hughes and Raybould to determine the explosibility of mine atmospheres. Similar interpretations can be performed by computer. A USBM report (IR 1069, 1977) by G.E. Smith and J.W. Nugent presents two programmes for use on a programmable, hand held, calculator, to determine the explosibility of gases. This report presented two programmes, one of which was adapted from calculations presented in the Bureau of Mines' IC 7901. The second programme used Le Chatelier's law for determining the total combustible and upper/lower explosive limits for mixtures of combustible gases.

9.7.3 Recommendations

It is recommended that CBDC review the present availability of Computer programmes that may be used to predict ventilation behaviour during fires with particular regards to contamination of escape routes by smoke. It is also recommended that the programmes available for determining the explosibility of gases are reviewed with a view to ensuring that CBDC has access to a

programme which is most suitable for the conditions found in the Sydney Coalfield Mires.

Of these two recommendations, the second is considered to be the most important.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 INTRODUCTORY COMMENTS

10.1.1 Measures Introduced By CBDC

The mine fires of recent years in CBDC mines have resulted in strong measures being taken towards minimizing the risks and dangers that mine fires create.

The geological predictions of sandstone bands and trials with a new shearer cutting drum are indicative of CBDC's efforts to overcome incendive sparking. The program of replacing combustible materials, where practical, is aimed at reducing the spread and intensity of fire. The introduction of anhydrite packs to replace wood chocks is an important part of this program since it also improves the face ventilation.

The innovative ventilation scheme that has been demonstrated, in which the intake air flow can be reversed in the main conveyor slope in the event of a conveyor fire, is a measure of CBDC engineering involvement in developing fire combat techniques. It is highly recommended that this scheme be refined to install normally open, steel doors, instead of relying on an inflatable stopping and that ways to speed up the change-over procedure be examined.

The now well established control room centres and the continuous, remote, environmental monitoring systems are providing an excellent means for the early detection of fire together with the communication facilities necessary for effective emergency incident control and orderly evacuation.

One of the most impressive features of CBDC's efforts is the provision of fire fighting equipment. Underground conveyor drives are fitted with automatic extinguishing systems and conveyor belt lines have well marked regularly tested fire hydrants and hose facilities. There is an abundance of extinguishers and fire combat equipment. The CBDC mines must now rank as some of the best equipped of Canada's mines. This is strengthened by a system of regular site checks and evaluations to ensure that fire fighting equipment is maintained in a state of readiness.

10.1.2 Continuation of Improvement

A review of the CBDC fire protection accomplishments shows that, up to now, efforts have been devoted mainly to:

- . fire detection
- . fire combat
- . evacuation

Apart from the attention being given to incendive sparking at the shearer drum, efforts have been directed towards the activities which follow the outbreak of fire rather those which prevent the outbreak of fire.

The action programs of CBDC were necessary and considerable sums of money have been spent to put them in place. In these areas, CBDC have largely met their immediate objectives and further cost/benefits will be increasingly difficult to attain. It is now strongly recommended that CBDC move to a follow-on program that will concentrate on Fire Prevention, and increasing the skills needed to mobilize and use the fire combat equipment now in place.

10.2 FIRE PREVENTION

10.2.1 Opening Remarks

The various sections of this Stage II Report contain general observations related to fire prevention but they also call attention to specific areas where fire prevention can be improved in the CBDC mines. These improvements are often related to technical matters but, common to the different aspects of fire prevention, there is an important human element. Successful fire prevention ultimately depends on the attitudes, knowledge and cooperation of people - at all levels of the organization.

10.2.2 Conveyors

Enough has been said in the report to show that fire prevention in this area requires a determined cooperative effort from engineering, mine management and the workforce. Improved conveyor transfer stations are where the greatest benefits can be realized. Improved life of idlers is a close second.

Technical success in this area will make for a more efficient operation, help do away with never-ending conveyor cleanup and improve morale.

10.2.3 Maintenance

There were many indications that maintenance (particularly electrical maintenance) falls short of the required standards. Improvements in this area can contribute greatly to fire prevention by reducing the number of "flashes". Maintenance staff are technically competent but the frequency and types of incidents suggest that procedures and work standards are not commensurate with ability.

In the operational/mechanical area malfunctions were noted that had persisted for some time (for example a haulage rope which, through constant rubbing, had cut deep into the steel base frame of the hauler). This indicates a willingness on the part of both workers and mine officials to accept sub-standard installations.

Improving installation, inspection and maintenance standards must play a major role in future fire prevention programs. A number of specific recommendations have been made in the report where corrective actions can be started.

10.2.4 Operational

Personnel engaged in the mining operations can contribute to fire prevention by practising tidiness in the mine and taking care of equipment - especially trailing cables. A fire prevention scheme should include educational programs which guide all mine personnel to a realization of their individual and collective responsibilities for fire prevention. The full participation of management and the support of the Unions will be essential ingredients for doing this.

10.3 FIRE FIGHTING TRAINING

10.3.1 Need for Training Improvement

New employees in CBDC are given classroom type instruction about the dangers of mine fire, how to handle fire extinguishers and how to don self-rescuers but almost nothing on fire prevention, fire detection or hands-on job-site practice. During the visits to the mines little was said about training except evacuation practices and getting the fire-cars into the mine.

The observations and comments made in Section 10.2 draw attention to the importance of the human element, the attitudes, knowledge and cooperation of people. Examples are given which indicate that the human element in CBDC is the key to fire prevention and it is strongly recommended that fire fighting training be improved as soon as possible.

10.3.2 Formation of an Executive Group

There are many ways in which fire fighting training can be approached. The training envisaged in this report seeks to inculcate responsible work attitudes as well as teaching how to handle fire fighting equipment. For this reason it is believed a step by step, integrated, corporate approach is required that is more than a typical Mine Training Officer could be expected to develop.

It is suggested that the formation of a small executive group, reporting to senior management, be considered as a way to proceed. This group would oversee the development of a more thorough and extensive fire training program; they should receive strong, active, support from the mine managers as well as other management levels of the Mining Division.

The "Group" should recognize fire fighting training as an opportunity to educate workers in fire prevention and detection, as well as in the ability to take appropriate immediate action. The educational aspect of the training should deal with worker responsibility and the work-site practices of individuals and work groups all of which play such an important role in reducing the number of fire incidents.

The "Group" should address:

- . The structuring of a fire fighting training scheme
- . The development of training courses - their content and who will prepare them
- . The training of instructors.

There should be fire fighting training courses for:

- . All new entrants - a common basic course
- . Mine supervisors and officials
- . Mine management on establishing guideline and directing fire fighting efforts
- . Underground work teams who normally work together or near together. This should mainly consist of practice drills.

Suggestions on course content are outlined in Section 6.

Obviously, not all this program can be put in place at once. A start should be made in overhauling the "new entrants" course and commencement of underground team practice drills. These should be followed by the supervisors courses.

The details of how the program should proceed and be developed would be handled by the "Group" - this report simply recommends the principle and suggests possible implementation action.

10.3.3 Involvement of the Mines

The best results will undoubtedly be obtained by the individual mines participating in the development and subsequent adoption of the training principles and the course material. Following this, they should be encouraged to develop their own improvements and innovations. Competiveness between work crews

and mines should be encouraged as a means of motivating mine personnel and promoting a free exchange of innovative ideas.

Apart from moral support for the program, managers should be prepared to:

- . Make arrangements for on-the-job fire practices.
- . Accept constructive criticisms and proposals for changes from the workforce.

10.4 AVAILABILITY OF TRAINING FACILITIES

10.4.1 Instruction Room

Training sites will require an indoor instruction room, ideally fitted with:

- . blackboard and notice board;
- . flip chart; and
- . audio-visual equipment - overhead
 - VCR and viewer
 - slide projector

Arrangement options would include, for example, whether each mine would have its own training room or whether one, central, room would be preferred. In deciding this it should be remembered that a great deal of the training will be practical and there should be an area near the training room where extinguishers and hoses can be used.

10.4.2 Practical Training

It is important that training schemes incorporate underground practices at actual job-sites. The workers from the job-site vicinity being the participants. This ensures that they become intimately familiar with the equipment at their disposal and with the types of fire or heating likely to be encountered in that locale. The exercises should try to engender an attitude of care for their work place.

10.4.3 Realism in Training

It is desirable to create realistic effects of a mine fire so that miners can learn how best to deal with the difficulties of smoke, heat and flame. Obviously this is very difficult to do in an operating mine even if special sites can be utilized. Flame can be simulated by coloured electric lights and harmless smoke could be generated where it can be exhausted directly into a return shaft. Alternatively loss of visibility might be simulated by participants using "smoked" goggles. There is considerable scope for innovative methods for creating realism.

10.4.4 A Fire Training Gallery

The construction of a "fire training gallery", that would incorporate all the required training features is another option to consider.

Such a facility would have:

- . Lecture room with audio-visual equipment;
- . An indoor hands-on practice area;
- . An outdoor, hands-on, practice area where real fires can be extinguished; and

- . Mine simulation galleries where, smoke, heat, flame and sound effects can be used.

A suitable site would have to be selected and the cost of building and operating such a gallery assessed. It would then be for CBDC to determine:

- . The degree of fire fighting training they wish to introduce; and
- . The extent that training can be adequately conducted in existing facilities and the mines.

The costs of constructing and operating a gallery will be provided in Stage III of this report. It can then be decided by CBDC whether to use a gallery or their existing facilities.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Planning the Re-Opening of Lynemouth Colliery - E.J. Price, The Mining Engineer (U.K.), May 1969.
2. Sealing off and Re-Opening following an Ignition at Astley Green Colliery - Coxen, Flighten, and M.B. Jones, The Mining Engineer, June 1969.
3. The Possibility of the Occurrence of Fuel Rich Mine Fires - A.F. Roberts and J.R. Blackwell, The Mining Engineer, September 1969.
4. Michael Colliery: Containing a Fire and Making Preparations for Recovery - 1967 - W. Rowel..., The Mining Engineer, November 1969.
5. Incident at Daw Mill Colliery - A. Callis, The Mining Engineer, September 1970.
6. Fire Retardant Treatments for Mine Timber - D.G. Wilde, The Mining Engineer, march 1972.
7. Sealing Remote Sampling and Re-Opening following an Ignition and Fire at Thurcroft Colliery - Chapman Hartley, The Mining Engineer, June 1972.
8. Fire at Ogilvie Colliery - Robinson Evans and Morgan Adams, The Mining Engineer, September 1972.
9. Cadley Hill Fire - Skelding, The Mining Engineer, October 1979.

10. Fighting Mine Fires with Nitrogen in the German Coal Industry - W. Both, The Mining Engineer, May 1981.
11. The Use of Nitrogen to Control Spontaneous Combustion Heatings - L. Harris, The Mining Engineer, June 1981.
12. Colliery Explosions and Fires - Their Influence on Legislation and Mining Practice - F. Furton, The Mining Engineer, September 1981.
13. The Use of Nitrogen at Fryston Colliery - Wartell and Walker, The Mining Engineer, July 1983.
14. Precautions Against Frictional Ignitions Associated with Coal Cutting and Tunnelling - J.T. Pearey, The Mining Engineer, April 1985.
15. Environmental Instruments - L.R. Cooper, The Mining Engineer, July 1984.
16. The Financial Aspects of Spontaneous Combustion-Flighton, The Mining Engineer, July 1986.
17. The Sealing of a Fire in L11 Main Gate at Seafield Colliery - Jones, The Mining Engineer, July 1987.
18. The Detection of Heatings and Fires - W.R. Robertson, Private, paper 1981.
- 18a. The Monitoring of the Atmosphere and Fires - W.R. Robertson - Private, paper 1981.
19. Fire Fighting - NCB Industrial Training Branch, 1978.

20. The Aga Spiro Mine Escape Breathing Apparatus, The Mining Engineer, June 1978.
21. Underground Coal Mine Fire Control with Inerting Systems - A Study - J.P.L. Bacharach and A.M.C.L., April 1984.
22. The Application of Pressure Balancing Chambers to Control Air Movement in Sealed Areas - Jolliffe, Raybould, The Mining Engineer, August 1961.
23. The Houghton Main Explosion (Summary), The Mining Engineer, March 1976.
24. Some Recent Researches on Barriers Against Coal Dust Explosions - Eioner and Rae, The Mining Engineer, February 1971.
25. Fire Retardant Coatings for Mine Timber - The Effect of Thickness - Wilde and A.F. Roberts, The Mining Engineer, December 1968.
26. Fire Retardant Coatings for Pit Timber - Guider, T.I. Mining Engineer 113, 53/54.
27. A Report of Model and Full Scale Experiments on Firedamp Roof Layers - I.O. Jones, The Mining Engineer, March 1969.
28. The Design and Development of a Triggered Barrier System at SMRE - Ramsay, Himley and Walerhouse, March 1971.
29. Ignitions of Firedamp by Friction During Rock Cutting- Powell and Billinge, The Mining Engineer, May 1975.

30. Recent Experimental Studies on the Wearing of Filter Self Rescuers - Johnston, Bentley and Lowe, The Mining Engineer, June 1979.
31. The Developments in Mining Science Re the Detection of Spontaneous Combustion - Briddle, The Mining Engineer, July 1981.
32. Welsh Explosions and the Current Hazard - A.W. Davies, The Mining Engineer, April 1982.
33. Further Developments in Monolithic Packing in the Warwickshire Coalfield - L. Collier, The Mining Engineer, April 1984.
34. Developments of Monolithic Packing Systems Within the Western Area - Flighton and Cooper, The Mining Engineer, June 1984.
35. A Review of Monolithic Pumped Packing Systems - Clark and Newsom, The Mining Engineer, March 1985.
36. Pump Packing Developments of Rowhurst 304 - Face at Flem Heath Colliery - Mifflin, The Mining Engineer, January 1986.
37. Control of a Heating at Ellistown Colliery - Turner, The Mining Engineer, November 1986.
38. A Co Self Transmitting Electrochemical Belt, Private paper.
39. Fire at Michael Colliery, Fife - Inquiry Report - HMSO, September 19, 1967.

40. Fire at Auchengeich Colliery - Inquiry Report - HMSO, September 18, 1959.
41. Report of Subcommittee on Mining Explosions - Coal Industry National Consultative Council - Safety and Health Committee, February 1959.
42. Ignitions of Coal Dust by Shotfiring - Loison and Sartorius (France), Paper 38, The 8th International Conference of Directors of SMR 1954.
43. The Salt Crust Method of Roadway Treatment - Linaive SMRE, Paper 38, The 8th International Conference of Directors of SMR 1954.
44. Convection Effect from Underground Fires - The Backing of Smoke Against the Ventilation - Eisner and Smith, Paper 38, The 8th International Conference of Directors of SMR 1954.
45. The Use of Models in the Investigation of Underground Methane Explosions - Fitman, SMRE Report, No. 163, February 1959.
46. Practical Aspects of the Foam Plug Method of Fighting Large Mine Fires - Linaive, SMRE Research, Report No. 171, February 1959.
47. A Manual on Mines Rescue, Safety and Gas Detection - by J. Strong and P. MacKenzie Wood - Auscue Publishers, P.O. Box 137, Woonana NSW 2517, Australia.
48. Ignitions, Explosions and Fires - Proceedings of a Symposium at the University of Woollongong 12-15 May

1981, The Australian Institute of Mining and Metallurgy.

49. The Effects of CO on Men and on Canaries - Dr. T.D. Spencer, The Mining Engineer, May 1959.
50. Rapid Determination of the Explodability of Mine Fire Gases - Hughes and Raybould, The Mining Engineer, October 1960.
51. Symposium on the Prevention of Spontaneous Combustion- Proceedings, The Mining Engineer, 1970.
52. Drainage of Methane from Sealed Areas - D.C. Yates, Steel and Coal, September 14, 1962.
53. Golborne Explosion Caused by Electrical Sparking, The Mining Engineer, December 1979.
54. The Design and Development of a Triggered Barrier- Hinsley et al, March 1971.
55. Mine Fires - Prevention and Control - P. Thorp, Canadian Mining and Metallurgy Bulletin, November 1974.
56. Sealing off Fires Underground - Institute of Mining Engineering, 1983.

APPENDIX A

**RECOMMENDATION FOR COMBUSTIBLE PRODUCTS USED UNDERGROUND,
ELIMINATION/REPLACEMENT**

AREA	SUBSTITUTION PROCESS					
	RECOMMENDATION	SHORT TERM TIME	RESPONSIBILITY	LONG TERM TIME		
Lagging				Investigate possibility of replacement corrugated sheet by mesh in slopes Implement packing for intake slopes in first stage for belt slopes Study & investigate automatic profile & direction control systems Treat exposed existing lagging on intake slope by coating Build Central Wood Treatment Plant Use treated wood only	6 Months 12 Months 12 Months 24 Months 24 Months 24 Months	Chief Mining Engineer Director Mining Engineer General Managers Director Mining Engineering Chief Mining Engineer, General Managers Director Eng. Services, Dir. Mining Eng. General Managers General Managers
Spacers	Design roof support for every intersection/excavation		Mine Engineers	Use only treated wood where wood spacers are required	General Managers	
Stoppings/Regulators	Replace all wooden structure with concrete blocks, steel frame & doors.	6 Months	Mine Engineers, Production Managers	Develop Corporate Standard for the construction of permanent stoppings/regulators	6 Months	Chief Ventilation Engineer
(a) Permanent						
(b) Temporary	All exposed wood to be covered with a cement based material (shotcrete or block-bond) or covered with sheet metal	6 Months	Production Managers	Develop a new design for temporary stoppings/regulators using non-combustible materials	12 Months	Chief Ventilation Engineer, Dir. Eng. Services

RECOMMENDATION FOR COMBUSTIBLE PRODUCTS USED UNDERGROUND. ELIMINATION/REPLACEMENT

AREA	SUBSTITUTION PROCESS			
	SHORT TERM		LONG TERM	
	RECOMMENDATION	RESPONSIBILITY	RECOMMENDATION	RESPONSIBILITY
Cribbing Blocks	Use concrete blocks in main slopes	Once agreed upon	Chief Mining Eng., Production Manager	Director Mining Engineering
Equipment Guards	Replace with steel or wire mesh	1 Month	Maintenance Managers	
Equipment Platforms	Replace with steel and non-combustible materials	6 Months	Maintenance Managers	
Belt Drive Attendant Encl.	Replace with non-combustible material	6 Months	Production Managers, Mine Engineers	Director Eng. Services
Belt Cross Overs	Standardize Steel Structure Design	3 Months	Chief Civil Engineer	Production Managers
Elevating & Levelling Belt Structure	Use concrete levelling blocks or belt suspension where possible for new installations	Once agreed upon	Production Managers	Production Managers
Walkways/Travelways	Replace wood with crushed rock, otherwise use expanded steel	6 Months	Production Managers	Production Managers, Mine Engineers
Wooden Props	Replace with steel props where possible		Production Managers	Production Managers
Rail Sleepers	Investigate possibility of using concrete sleepers.	3 Months	Chief Mining Eng., Dir. Eng. Services	General Managers Production Managers

RECOMMENDATION FOR COMBUSTIBLE PRODUCTS USED UNDERGROUND ELIMINATION/REPLACEMENT

AREA	SUBSTITUTION PROCESS				
	RECOMMENDATION	SHORT TERM TIME	RESPONSIBILITY	RECOMMENDATION	LONG TERM TIME
Benches	Investigate alternative for wood replacement	6 Months	Dir. Engineering Services	Use non-combustible material for construction	RESPONSIBILITY Production Managers
Stairs	Replace by non-combustible material	6 Months	Operations Managers		
Ladders	Investigate alternative non-combustible material designs	6 Months	Dir. Engineering Services	Use only non-combustible material or treated wood for construction	Production Managers
Wedges				Use treated wood only	General Managers
Footpieces				Use treated wood or steel plates	General Managers
Signs	Replace following Corporate Specification	3 Months	Safety Co-ordinators Manager Safety		
Rescue team underground clothing	Treat all clothing with fire safe retardant	6 Months	Chief Ventilation Engineer		

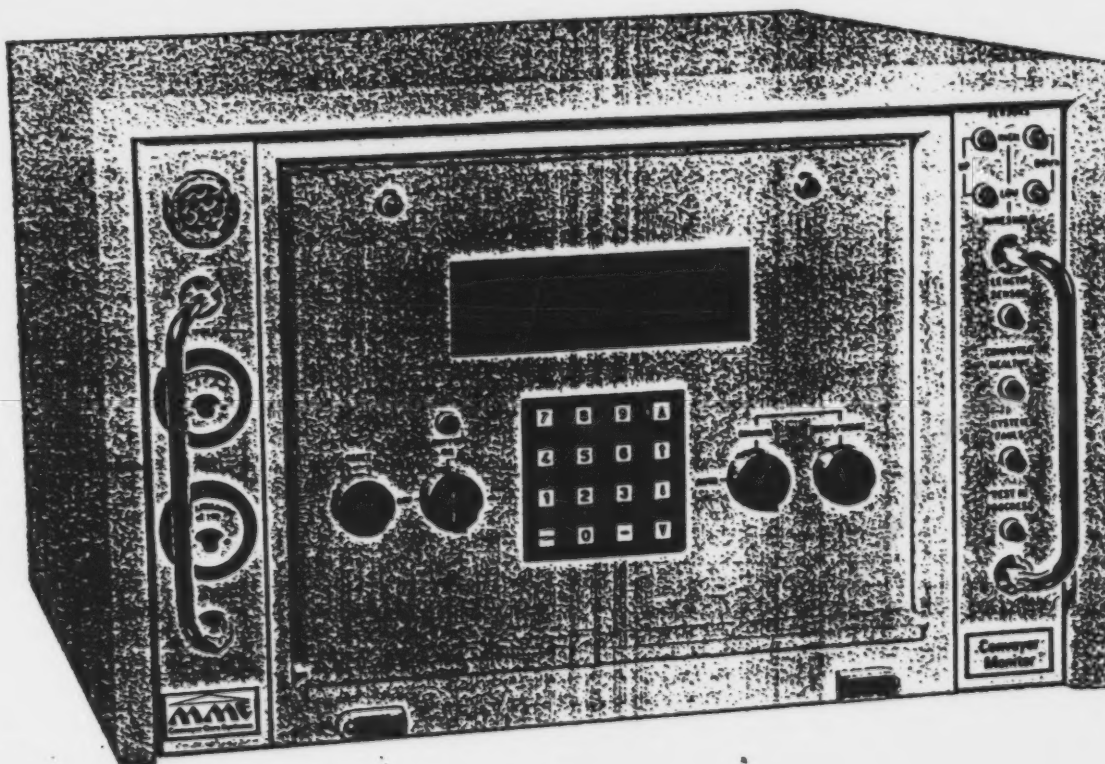
APPENDIX B

MME CONVEYOR IDLER MONITOR - DATA SHEET



CONVEYOR IDLER MONITOR*

DATA SHEET



It has long been appreciated that belt conveyors are a major source of fire in underground mining environments, and tragic incidents which have occurred in the past at Chatterley Whitfield and Creswell Collieries in England and more recently at Schlagen and Eisen in West Germany, serve to remind just how severe the consequences can be.

MME Conveyor Care Systems, part of the Fenner Group, has developed the Conveyor Idler Monitor in response to one particularly serious problem encountered within underground conveying—that of frictional heat build-up associated with faulty and failing conveyor idler rollers.



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Conveyor Care Systems

Background

Although it is true that much progress has been made in recent years to alleviate this problem of frictional heating, the number of fires reported each year within the U.K. coal-mining industry originating from faulty or failed conveyor idler rollers remains disconcertingly high. Table 1 below provides an analysis of fires associated with idler rollers over the twenty-one year period from 1963 to 1983, and this bears testament to the significance of this category of fire within the overall picture.

Table 1
Underground conveyor fires associated with idlers and rollers 1963-83.

Year	Bottom idler rollers		Top idler rollers	Other rollers	All conveyor fires
1963	5				9
1964		7*			29
1965		8*			20
1966	14				26
1967	15				18
1968	21				26
1969	12				24
1970	13				32
1971	4				16
1972	7				16
1973	10				24
1974		8*			21
1975		7*			22
1976	5			4	18
1977	7		2		22
1978		7*			25
1979	4		3	2	17
1980	9		3		28
1981	15				20
1982		12*			30
1983		12*			24
Total	141	61*	8	6	467

*Published figures do not differentiate between the two categories.

Source: HSE Annual Reports.

The two overriding statistics available from this tabulation are:

- 1 Over 46% of all underground fires are still attributable to faulty conveyor idler rollers whose bearings have either worn or collapsed.
- 2 At least 92% of these roller-associated fires are specific to bottom return idlers as opposed to top pushing idlers or bend pulleys.

The Problem

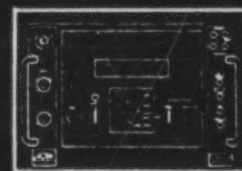
The problem on bottom rollers is principally that of the idler roller bearing failing either prematurely or, more often, through the ingress of dirt or moisture through the bearing seals. The heat generated through the various stages of the subsequent bearing collapse is well documented, and it is known that the most dangerous point is immediately prior to the bearing seizing. Up to this point the majority of heat is generated inside the bearing, causing it to rise in temperature. This causes the idler shell itself to heat up where it is eventually dissipated by radiation into the air or conducted into the moving belt. When the conveyor stops however, the bearing becomes extremely hot, and temperatures up to 300°C have been recorded primarily because there is no efficient means of heat dissipation. The potential danger here is obviously that coal dust, spillage or rubbish which accumulates around return rollers, particularly on the tight side of the conveyor, will ignite. The problem is further exacerbated by the fact that this stopping of the conveyor often coincides with the withdrawal of labour at shift change where fires are more likely to develop undetected.

Principle of Operation

The MME Conveyor Idler Monitoring system uses infra-red sensors, usually two pairs in a fixed location, to detect thermal gradients or hot spots on the conveyor belting itself, and works on the principle that when the conveyor stops the frictional heat produced by a faulty or failing component will soak into the belting. Once the conveyor starts up again, the localised hot spot will pass over the sensors and is immediately detected. Based on state of the art micro-processor technology, the Monitor is not only capable of *identifying* these hot spots, it is

MME CONVEYOR IDLER MONITOR General Arrangement

Monitor
Unit



MME

Conveyor Care Systems

also capable of **locating their position** along the length of the conveyor, either by a distance from datum or by a line stand number reference.

More significantly, by virtue of correlation procedures programmed into its computer, the unit is capable of **identifying and predicting roller failure in the early stages**, when remedial action can be taken before critical temperature levels are ever encountered. Used in this mode, the unit clearly avails itself to the mechanical engineer as a unique tool within his preventative maintenance schedule.

Physical Description

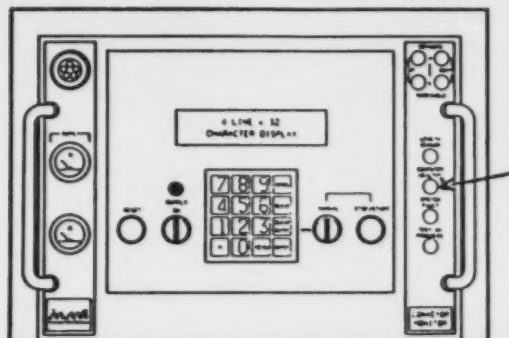
The MME Conveyor Idler Monitor is designed to meet the U.K. HSE requirements for intrinsic safety and requires the addition of an intrinsically safe 7.5V/1.5 Amp power supply to do so.

The unit itself is housed in an IP55 mild steel enclosure, with a hinged dust proof cover protecting the controls when not in use.

A working system requires up to seven sensors which connect to the underside of the unit together with the power supply. Up to 3 pairs of sensors can be used to monitor the infra-red radiation from the surface of the belt whilst the seventh sensor acts as a displacement transducer monitoring the movement of the belt. Access to the front panel controls is gained by opening downwards the hinged dust-proof cover with the key provided.

The infra-red heat sensors are housed in robust mild-steel enclosures and are protected from the ingress of dust and dirt by a replaceable window. Access to the sensing element itself is gained by removal of the window, though this should rarely be necessary.

The length transducer is sealed at the manufacturing stage and therefore only the complete idler can be replaced.



Keyboard & Display

In order to provide a versatile man-machine interface the unit is supplied with a 4 line x 32 character alpha-numeric display together with a sixteen-key functional keyboard. This provides the operator with a simple menu driven installation and operating procedure by which data input and retrieval is achieved.

Control Switches

In addition to the display and keyboard there are four control switches which perform basic operations within the unit. The first two, on/off and reset are self-explanatory. The remaining two controls select firstly manual or automatic mode of operation, initiated by the menu driven operator interface and secondly stopping and starting of test procedures in manual mode.

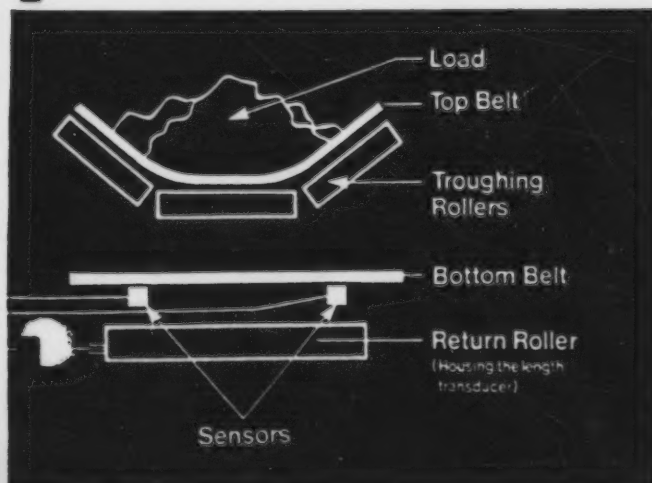
Indicators

The light emitting diodes (LED's) situated on the right hand side of the unit are used as indicators for functional information whilst the system is in operation. Two of these form the basis of the diagnostic procedures and indicate when a SYSTEM FAULT has been detected together with a COMPUTER HEALTHY watchdog routine.

The correct operation of the sensors, both heat and length, is indicated by five LED's and are labelled appropriately.

The LENGTH SENSOR LED will flash continuously whilst the conveyor is in motion and the four remaining ones indicate signals received above the established threshold settings of the heat SENSORS.

A voltmeter and ammeter provide the power supply information together with a POWER ON beacon situated directly above the on/off switch.



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Conveyor Care Systems

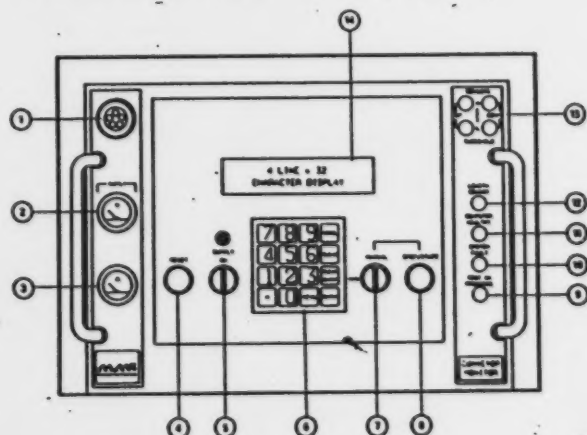
Power Supply

In order for the MME Conveyor Idler Monitor to conform fully with the requirements for intrinsic safety the unit is designed to operate from an additional power supply. This should be a suitably approved unit with a nominal output of 7.5 Volts at 1.5 Amps and is connected directly to the unit via the appropriate connector:

Connection Details

On the underside of the unit there are eight type 104 connectors, to which the necessary inputs are required.

- | | |
|-----------------------|--------------------------|
| 1. Audible Alarm | 8. Manual Stop/Start |
| 2. Voltmeter | 9. Test in Progress LED |
| 3. Ammeter | 10. System Fault LED |
| 4. Reset Switch | 11. Computer Healthy LED |
| 5. Power On/Off | 12. Length Sensor LED |
| 6. Keyboard | 13. Heat Sensor LED's |
| 7. Manual/Auto Switch | 14. Display |



AGENT

GENERAL SPECIFICATION

PHYSICAL SPECIFICATION

- ENCLOSURE
IP55 mild steel cabinet
- HINGED PROTECTIVE PANEL
Mild Steel sealed to IP55
- PHYSICAL DIMENSIONS
Size: 300 x 480 x 425mm
Weight: 34Kg

ELECTRICAL SPECIFICATION

- POWER SUPPLY REQUIREMENT
7.5 Volt/1.5 Amp DC4 type. MRD60616 or to B.S.6182
- POWER SWITCH
Single pole single throw
- INTERNAL SUPPLIES
5V and 10V DC
- POWER CONSUMPTION
Nominal 500mA at 7.5 Volts
- P.C.B. REQUIREMENT
CPU E200
INPUT OUTPUT E101
POWER REGULATOR E202
SENSOR INTERFACE MODULE
Internal connections via D type connectors (Front), DIN 41612 (Rear)

OPERATOR DEVICES AND CONVENIENCES

- 16-key functional keyboard for direct entry of all data
- LED indicators for monitoring and verification
- 4 x 32 alphanumeric display
- Control switches
- Audible alarm

MME

Conveyor Care Systems

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Member of the FENEC Group * Patent Pending



Volume

3

INCIDENCE AND POSSIBLE CAUSES OF
FIRES WITHIN COAL MINES OF
THE NOVA SCOTIA COAL FIELDS
AND ON MEASURES THAT CAN BE TAKEN TO
PREVENT SUCH FIRES

STAGE 3

259 pp

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FEBRUARY 16, 1990

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MICROMEDIA

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1.0 INTRODUCTION

1.1 REPORT STAGES I AND II

This report is Stage III of a three stage report. The first stage assessed the cost of underground mine fires in the Sydney Coalfield in terms of their direct cost to the mine and also the socio-economic cost to the community.

The second stage examined the conditions and fire risks in the Sydney Mines and the steps that can be taken to reduce the risks of mine fires. Attention was paid to the scope for research relevant to mine fires in the Sydney Coalfield.

The conclusions of Stage II stressed the need to improve fire prevention through fire fighting training. It was noted that training programs could be carried out at the existing mine facilities making use of practical training at underground sites, or a central training facility could be used. The decision on which route to take would be made by CBDC when cost estimates of a training facility were prepared in Stage III.

Stage II also noted the value of computer programs as aids to fire fighting.

1.2 STAGE III, THE FINAL STAGE

This third stage addresses the application of computers to aid fire fighting and lists programs available. It reviews foreign research facilities and their availability for research into fire fighting and fire prevention. The areas in which research relevant to the Sydney Coalfield might be considered are discussed.

The report ends with the description of a specially built fire training facility, its capital and operating costs and an example of a fire training program.

2.0 COMPUTER PROGRAMMES2.1 INTRODUCTORY COMMENTS

The development of the computer and now, more particularly, the desk top P.C., has provided an invaluable tool to speed up the diagnostics involved in fires. There are two principal areas where computers can be employed, in addition to planning and maintaining adequate ventilation for the mine in general; these are:

- a) Predicting the effects of fire on the normal ventilation and,
- b) Predicting the explosibility of mine atmospheres during fire fighting, sealing-off and recovery operations.

2.2 PREDICTING THE EFFECTS OF FIRE ON MINE VENTILATION2.2.1 Factors Affecting Predictability

The effects of fire on Mine ventilation depend on:

- . the three dimensional geometry of the mine
- . the intensity of the fire and the heat gradient of the atmosphere downwind of the fire
- . the rate of spread of the fire
- . the integrity of existing ventilation devices (i.e. doors, stoppings, air-crossings regulators). As temperatures increase, as fire approaches and/or if ventilation flows reverse, these devices may be destroyed or fail to operate properly.

2.2.2. Use of the Computer

The characteristics of the pre-fire ventilation and the geometry of the mine would be registered in the computer and the variables added, i.e. heat, loss of doors and stoppings. By appropriate software the data can be processed to show what the outcome is likely to be, i.e. changes in air flow quantity and direction, route taken by smoke and hot fumes.

The information can be processed speedily and "what-if" conditions can be quickly assessed. This allows evacuation and fire combat to be organized and directed with increased speed and confidence. A programme to do this is available from the U.S.B.M. Pittsburgh Research Centre - see the Ventilation Programmes listed at the end of this section, Table 2.1 as published in the "Directory of Mining Programmes" by Gibbs Associates, Boulder, Colorado.

2.3 PREDICTING THE EXPLOSIBILITY OF MINE ATMOSPHERES

2.3.1 Application

During the fighting of fires, sealing-off and recovery of sealed-off mine sections the mine atmosphere is constantly changing. The proportions of constituent gases may be moving towards or away from an explosive mixture. The trend is predicted on the basis of the typical "Coward Triangle" principle. However, it should be remembered that though this is a relatively simple concept, it is not necessarily a simple process to deduce a correct answer, particularly when a fire is in progress.

The heat from the fire distills tars and vapours; burning generates CO and CO₂. There may be Methane present (CH₄) and also, "fire gases", which include hydrogen. The "Coward Triangle", appropriate for "normal" mining conditions, shows the methane explosibility limits between 5% and 15%. However, under fire conditions, this can be in a constant state of change because:

- a) At high temperatures (say 500°C) the flammability limits of methane become 3% to 20%;
- b) In the presence of Hydrogen and Ethane, the lower limit of the Methane flammability is reduced;
- c) The presence of Carbon Monoxide and Hydrogen raises the upper limit, while Carbon Dioxide and excess Nitrogen reduce the upper limit.

These interactions are complex and may change rapidly during the course of a fire or sealing operation. The use of a computer to provide a rapid means of interpreting trends towards or away from explosive ranges is obviously of great benefit, especially to the safety of those directly involved in combatting the fire.

2.3.2 Explosibility Software

A P.C. programme for explosibility calculations, based on the Hughes/Raybould diagrams has been developed by the British Coal, Yorkshire Regional Laboratories, (See Sections 3.2 and 3.3.4 of this Stage 3 Report), the software is available from CANMET. The two non-Canadian Research Establishments actively pursuing this area of investigation are:

- The USBM Pittsburgh Centre and,
- The Australian Londonderry Centre N.S.W.

(See Section 3 of this Stage 3 Report).

2.3.3 Data Input and Sampling

It is important to remember that the value of computer analyses of mine fire conditions are dependent on the validity of the samples. Getting reliable, representative, samples is often very difficult. Under emergency conditions it is necessary to collect a large number of samples on a round-the-clock basis, the result is that:

- a) inexperienced persons are pressed into taking samples because there are too few trained sample takers; and
- b) emergency conditions usually dictate sample locations and often, sampling procedures.

The reader is referred to an excellent paper, "Interpreting The State of a Mine Fire", by Donald W. Mitchell and Frank A. Burns, (a copy of this paper is included in Appendix A) in which fifteen practical "Rules" are described for taking samples during the course of an emergency.

Once samples have been obtained they must be analyzed to get the input data for the computer. Clearly, the analyses must be as speedy and as accurate as possible. A gas chromatograph, carefully calibrated and used by an experienced operator gives quick, accurate results. Emergency Plans should provide for this apparatus, and an operator, to be available at site at the earliest possible moment. The 'Trickett's Ratio' should be used to test the reliability of sample results.

2.3.4 Recommendations

- a) CBDC should review the facilities and procedures they have established to see whether large volume, sampling, analyzing and interpretation of analyses results, during a fire emergency, can be improved.
- b) A training programme for samplers should be instituted to ensure that there are sufficient sample takers who can be called on in an emergency; this should include rescue team workers.

Finally, it is worth repeating the conclusion of the technical paper previously cited:

"Computations and diagrams are positive aids to persons responsible for extinguishing a mine fire. They permit forecasting trends and evaluating the effectiveness of fire-fighting activities. Abrupt changes, however, occur without warning. Diagrams and computations must never be allowed to displace caution and good sense.



DIRECTORY OF MINING PROGRAMS

A Comprehensive Directory of Computer Programs
Related to Mining Applications

GIBBS ASSOCIATES
Energy and Minerals Information Specialists
P.O. Box 706 Boulder, Colorado 80306-0706
(303) 444-6032

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VENTILATION

ARIZONA COGS
PO Box 44247
Tucson, AZ 85733-4247
Angus Scott-Fleming

AIRLAB

This program teaches fundamental concepts (using graphs and tables) with experiments in temperature-vapor pressure; operation of a psychrometer; and adiabatic lapse rate/atmospheric stability. A well-equipped laboratory is simulated using digital and analog readouts.

LANGUAGE: NA
MEMORY REQUIREMENTS: 256K
OPERATING SYSTEM: DOS
HARDWARE: IBM PC and compatibles.
PRICE: \$50.

PLANCK

The program gives graphs of the radiation spectrum of an emitting surface whose temperature can be varied up to 12,000 degrees K. Linear and log axes, monochromatic radiation, and radiation emitted within a user-specified band are permitted.

LANGUAGE: NA
MEMORY REQUIREMENTS: 256K
OPERATING SYSTEM: DOS
HARDWARE: IBM PC and compatibles.
PRICE: \$50.

AUSTRALIAN COAL INDUSTRY
RESEARCH LABORATORIES, LTD.
14-30 Delhi Road, P.O. Box 83
North Ryde, NSW 2113 AUSTRALIA
(02)887-3777. Telex 27251

MINVENT - Mine Ventilation Simulation System

Input of normal ventilation survey data, such as airway resistance, pressure drop and air quantity, allows calculation of the network by the Hardy Cross method. This may be used to generate tabulated reports, graphs of fan curves and fan operating points., network distribution diagrams, showing pressure drop, resistance and cost per year and plans of airflow distribution.

Up to 50 regulators and up to 10 surface or underground fans can be specified. Airflow across goafed areas may be represented as leakage paths. Natural ventilation pressure can be considered. Network diagrams may be superimposed on mine plans generated by MINDRAFT.

LANGUAGE: FORTRAN
MEMORY REQUIREMENTS: 2.5 Mb
OPERATING SYSTEM: VMS, AOS
HARDWARE: DEC VAX family, Data General MV series. Wide variety of graphics terminals and digitizers.
PRICE: Available on Request.

FLOYD C. BOSSARD & ASSOC. INC.
P.O. Box 3837
Butte, Montana 59702
406-494-2280
Floyd C. Bossard

MIVENDES - Mine Ventilation System

A mine is represented by a series of nodes which define the beginning or end of an airway or area in the mine that has common criteria. All calculations are conducted within the branch defined by the nodes. Data is input relating to elevations, airway length and cross section, friction and shock loss factors, inlet air temperature, required volumes of air and other pertinent information. When the network is solved, a series of reports are generated which provide the following information: Airway resistance, heating and cooling of air, air psychrometry, absolute barometric pressure, diesel exhaust gases, air flow, primary and booster fans, methane, and radon.

LANGUAGE: FORTRAN
MEMORY REQUIREMENTS: 32Kb
OPERATING SYSTEM: RSTS/E
HARDWARE: CDC, DEC
PRICE: Available on Request

CANMET
 Technical Information Division
 555 Booth St.
 Ottawa, Ontario K1A 0G1 CANADA
 Mr. R.T. Blake

**THERMODYNAMIC MINE
 VENTILATION**

The program uses the modified Hardy Cross method to balance the network. Linear interpolation of user supplied fan characteristics and a routine to remove stalled fans ensures a practical solution.

Branch resistances can be calculated from branch characteristics or with a K factor. Other data input includes branch end elevations, average air density, and moisture content.

Flows in a mesh containing a fixed quantity branch is balanced so that the fixed flow is maintained. Any number of update and modification runs of the program can be performed in a single run. Changes are cumulative.

Output includes a listing of the input data, fan and branch characteristics, air power, and cost. A plot of the network can be obtained on a Calcomp plotter.

LANGUAGE: FORTRAN 77
MEMORY REQUIREMENTS: NA
OPERATING SYSTEM: NA
HARDWARE: CDC Cyber 730. Calcomp plotters.
PRICE: Charge for reproduction and media.

HTMI
 B.P. No. 14
 Verneuil-en-Halatte, 60550, FRANCE
 33.44.24.24.24, Telex: 150170 F

DISTRIBUTED BY: Gibbs Associates
P.C. VENT

P.C. Vent is a conversational ventilation network analysis program. The system includes on-line documentation and is fully interactive. It can handle about 120 nodes, 200 branches. A network calculation of around 80 iterations requires approximately one minute. With 256Kb RAM it can handle up to 200 branches and 500 nodes. Input to the program includes: branch

resistance, ground level head, depth for each node, characteristic curve for each fan.

Calculations provided include the mine ventilation network, fan working conditions, determination of adequate resistances to ensure fixed airflows in strategic places, and variations of air temperatures from one place to another.

LANGUAGE: FORTRAN
MEMORY REQUIREMENTS: 192-256 KB RAM
OPERATING SYSTEM: MSDOS
HARDWARE: IBM PC or XT, MICRAL 30
PRICE: \$1000

VENDIS - Mine Ventilation Software

VENDIS provides mine ventilation network analysis with interactive computer input/output and graphic display. The network can be input with a digitizer and the user inputs node numbers and depths. For each roadway, other values are entered for resistance, temperature and fixed air flows. Fan characteristics are entered separately. Airflows are calculated using the Hardy-Cross method. Output can be viewed for a specific roadway and the parameters can be modified. The condition of the entire network can also be displayed.

The display scale can be changed and a perspective can be plotted. Natural ventilation is considered when changes in density result from different temperatures in roadways. The program runs with the Tektronix 4111 terminal or the Afigraf 6080 for interactive graphics display of ventilation networks.

LANGUAGE: FORTRAN
MEMORY REQUIREMENTS: 128 KB RAM
OPERATING SYSTEM: MSDOS
HARDWARE: IBM PC or XT, MICRO-PDP11, Honeywell Level 6. Tektronix 4111 graphics display console, AFIGRAF 6080.
PRICE: \$12,000

VENTILATION

LYNX GEOSYSTEMS
400 - 1199 West Pender St.
Vancouver, BC V6E 2R1 CANADA
604-682-5484, FAX: 604-669-3659
Garth Kirkham

747-9A Sheridan Blvd.
Lakewood, CO 80214
303-233-LYNX, FAX: 303-233-0273
Brian Savage

c/o Wright Engineers Ltd.
Mezzanine Level
357 Bay Street
Toronto, ONT M5H 2T7 CANADA
416-363-6621
Bruce Clifford

LYNX SYSTEM: VENTILATION ANALYSIS

This package accommodates three-dimensional networks with forced ventilation (fans), natural ventilation, or both. The interactive nature and 3D graphics permit rapid interpretation of air flow and pressure results and respecification of network branches, fan characteristics and airlocks, allowing rapid convergence on the optimum design solution.

Results are output in tabular format or 3-D perspective plots. The network designer may specify minimum airflow requirements in network branches of primary concern (e.g. operational stopes). In these cases the output will be flagged if the analytical results are below minimum requirements.

LANGUAGE: Fortran, C
MEMORY REQUIREMENTS: Application specific. 4Mb minimum
OPERATING SYSTEM: Unix System V
HARDWARE: Full 32 bit Workstations (HP9000, IBM RT, etc.)
PRICE: Available on request

MINE VENTILATION SERVICES, INC.
3717 Mt. Diablo Blvd., Suite 101
Lafayette, CA 94549
415-284-5912, 415-284-5924
FAX 415-284-4365
Martha S.J. O'Leary or Daniel J. Brunner

VENTILATION PROGRAMS

VNETPC - VNETPC is a self-teaching system for the prediction of airflows, pressure drops and operating costs in an underground ventilation system. Modifications to stored networks are entered rapidly for update exercises. Color coded graphical input/output of the network geometry, airflow, frictional pressure drops and operating costs distribution enables quick visual interpretation of the results. It is capable of modeling up to 500 branches.

This software was designed specifically to assist in the design, planning and control of underground ventilation systems. Using data from ventilation surveys or determined from known airway dimensions and characteristics, existing and conceptual ventilation circuits can be simulated so air-flow rates, frictional pressure drops and fan operating points approximate those of actual systems. The program incorporates a steady state gas distribution program which enables evaluation of gas concentration and volume distribution from measured or predicted gas source locations and magnitudes.

VNETPC is based on state of the art network analyses routines incorporating incompressible flow and steady state relations. Capabilities include:

- Evaluate networks up to 750 branches and 30 fans.
- Compute steady state gas concentration and volume distribution using balanced airflows.
- Process data either in Imperial or System International Units.
- Store up to 50 fan characteristic curves for development of a fan data bank.
- Accept branch input data in 5 forms: pressure drop and quantity; fixed resistance; airway physical characteristics; fixed airflow rate; inject/reject fixed airflow for simulation of compressibility effects or compressed air.
- Spreadsheet style editor.
- View or print designated section of the output.
- Digitize network from the plotter.
- Convert data from previous versions.

LANGUAGE: Compiled FORTRAN
 MEMORY REQUIREMENTS: 512K
 OPERATING SYSTEM: MS-DOS
 HARDWARE: IBM PC and compatibles. HP
 plotters are supported: 7470, 7475A, Draft
 Pro, 7580 series.
 PRICE: \$650. If you have an earlier version, you
 can upgrade to Version 3.0 for only \$300.

VENTILATION SOFTWARE

CLIMSIM - CLIMSIM simulates the variation
 in psychrometric conditions along any mine
 airway, shaft or slope. Data requirements
 include airflow and wet bulb/dry bulb
 temperatures at inlet, airway geometry and age,
 rock thermal properties, and power and positions
 of equipment and cooling plant. It investigates
 the many parameters that effect climatic
 conditions in mines. PRICE: \$450

SHAFTDIA - Given power costs, fixed or
 variable excavation costs and capital borrowing
 charges, SHAFTDIA calculates the optimum
 size of a shaft or airway for any given airflow
 rate. The program handles circular, rectangular,
 or arch shaped airways. PRICE: \$250

LANGUAGE: BASIC/FORTRAN
 MEMORY REQUIREMENTS: 256K RAM
 OPERATING SYSTEM: MSDOS
 HARDWARE: IBM PC/XT/AT or compatible
 PRICE: As noted above.

MSHA - Mine Safety and Health
 Administration
 P.O. Box 25367
 Denver, CO 80225
 303-236-2713
 Allen Fries

MINE VENTILATION DIGITAL SIMULATION AND ANALYSIS

The program is an adaptation and revision of
 the network simulation developed by Wang and
 Saperstein and utilizes the Hardy Cross
 adaptation of the Newton-Raphson iteration
 process to analyze a ventilation network. The
 program is modular and accepts data in a
 flexible format. Options used to fit fan curves
 include a least-squares fit, and Newton's divided

difference interpolating polynomial technique.
 The polynomial insures that the fan curve passes
 through more of the input points. The user
 specifies the presumed operating point of each
 fan and upper and lower limits beyond which the
 operating point is not allowed to go during the
 iterative computations.

Total pressure is computed and output for all
 nodes. Input data is obtained from quantity-
 pressure surveys for design of friction factor
 data. The program accepts other data such as fan
 characteristics, natural ventilation pressure data,
 fixed quantity branches, and flags to specify
 program options. An interactive program is also
 available to create input data files. Program
 listings and documentation are included in
 Information Report 1066 which is available
 from MSHA. The program code can also be
 obtained on a tape.

LANGUAGE: FORTRAN
 MEMORY REQUIREMENTS: NA
 OPERATING SYSTEM: Varies with computer
 HARDWARE: Most computers
 PRICE: Small charge for tape containing code

PENNSYLVANIA STATE UNIVERSITY
 Department of Mineral Engineering
 University Park, PA 16802
 814-863-1641
 Eric K. Albert

PSU/MVS - Mine Ventilation Simulation

This program is a detailed ventilation
 simulation program. The network is solved with
 the Hardy-Cross iterative technique.

LANGUAGE: FORTRAN
 MEMORY REQUIREMENTS: 280K
 OPERATING SYSTEM: Various.
 HARDWARE: Mainframes, IBM/PC [Batch]
 PRICE: \$250

VENTILATION PROGRAMS (Disk#2)

A diskette which runs on a microcomputer is
 provided which contains programs for several
 ventilation applications. The programs provided
 include the following:

- Microvent.V1.1 - solves a ventilation
 network with up to 50 branches and 5 different

VENTILATION

fans. The network is solved using the Hardy-Cross iterative technique.

- Ventilation Pressure Survey - calculates the pressure gradient based on the information from an altimeter survey. A sample data file is included.
- Ventilation Network Balancing - balances the air quantity within a ventilation network.
- Regulator Sizing - calculates head loss, shock loss, air velocity, and the area of a regulator for each airway to satisfy the quantities specified.
- Ventilation of a 5-entry Section - shows graphically the ventilation for the intersection of two 5-entry sections.
- Cost Analysis of Ventilation Shafts - performs a discounted cash flow analysis on the capital and operating costs of a ventilation shaft.

LANGUAGE: BASIC

MEMORY REQUIREMENTS: 64K

OPERATING SYSTEM: DOS

HARDWARE: Apple II series only.

PRICE: \$50

U.S. BUREAU OF MINES

Pittsburgh Research Center
P.O. Box 18070, Pittsburgh, PA 15236.
Telephone: 412-675-6751
Mr. Daniel Ng

MINE VENTILATION

The U.S. Bureau of Mines has developed a program to help in planning mine ventilation and for predicting the spread of contaminants through a ventilation system. The program is a microcomputer adaptation of the mainframe program developed by the Bureau and the Michigan Technological University. The results are identical to the mainframe version.

The program calculates airflow for any possible combination of airways and regulating devices. The spread of contaminants such as smoke, carbon monoxide, or methane in underground mines can be calculated for normal forced or normal convective ventilation conditions. The effect of a fire on the air quality of all portions of a mine can be examined and escape routes planned accordingly. Both planned and potential unplanned changes in the ventilation system can be examined. Data entry is done with a word processor or with dBase III.

LANGUAGE: FORTRAN

MEMORY REQUIREMENTS: 256KB RAM for handling 220 separate airways and junctions, or 640Kb for handling 600 airways and junctions.

OPERATING SYSTEM: MS-DOS

HARDWARE: IBM PC or compatible computers

PRICE:

U.S. BUREAU OF MINES

Dust Control and Ventilation Group

(See listing in Operations Monitoring section.)

VIRGINIA POLYTECHNIC INSTITUTE & SU

Department of Mining and Minerals
Engineering
Blacksburg, VA 24061-2899
703-961-6671
Telex: 710-875-3699
Richard Lucas

VENTSIM

This program utilizes one or a combination of three options to calculate the resistance of mine airways. These options are: 1) measures pressure drops and volumes, 2) calculates the friction factor, and 3) defines the friction factor. From these and other inputs dealing with the flow network, fans, regulators, and airways in a mine, the program calculates volumes, pressure drops, flow rates, horsepower requirements, and flow distributions. VENTSIM can be used to model, predict, and solve a number of problems dealing with ventilation networks.

LANGUAGE: FORTRAN-77

MEMORY REQUIREMENTS: NA

OPERATING SYSTEM: OS/MVS

HARDWARE: IBM Mainframe

PRICE: Available from NTIS, OCR Research and Development Report No. 1; Volume 1, PB 237053, \$20.00, Volume 2, Item No. 237054 for \$18.50. Also included with entire system on 3 tapes priced at \$450 each.

3.0 NON CANADIAN FIRE AND EXPLOSION RESEARCH FACILITIES

3.1 INTRODUCTORY COMMENTS

3.1.1 Statement of Work Requirements

The contract requires that fire and explosion gallery facilities available outside Canada are identified, together with their particular fields of research. It must be considered whether contractual research by these facilities is available and appropriate to the needs of the Sydney Coalfield and if so what might be the cost of this research. These Contract work requirements were further confirmed by the Management Committee at a meeting with them on November 4th 1988.

3.1.2 Inquiries and Questionnaires

Information was sought from non-Canadian Mine fire and explosion Research facilities concerning their research capabilities and possible contractual research arrangements. Establishments were contacted in:

- . United States
- . United Kingdom
- . France
- . Germany (FDR)
- . Australia
- . Poland

Two installations in Britain were visited by Mr. G. Jolliffe: Health and Safety Executive, Explosion and Flame Laboratory, Buxton (Dec. 2nd, 1988) and British Coal Corp., Yorkshire Regional Laboratories, (Oct. 21st, 1988). The Australian Londonderry Centre, N.S.W. was contacted by phone. Other facilities were contacted by letter and asked to complete and return a questionnaire.

3.2 NON-CANADIAN FACILITIES CONTACTED

The non-Canadian facilities contacted are listed below:

- a) United States Department of the Interior, Bureau of Mines
(U.S.B.M.)

Pittsburgh Research Centre
Cochrans Mill Road
P.O. Box 18070
Pittsburgh, Pennsylvania 15236-0070

Research Director, John N. Murphy

- b) Health and Safety Executive
Explosion and Flame laboratory
Harpur Hill
Buxton
Derbyshire SK17 9JN
U.K.

Deputy Chief Scientific Officer, Mr. J.A. Barton

- c) British Coal Corporation
Yorkshire Regional Laboratories
Golden Smithies Lane
Wath-on-Dearne
South Yorkshire U.K.

Regional Chief Scientist, Mr. Gordon Armstrong

- d) Charbonnages de France International
CHERCHAR
BP No. 2
60550 Verneuil - en-Halette
France

Counseiller du Directeur des Recherches, Claude Froger

- e) Bergbau - Forschung GmbH.
Hauptstelle für das Grubenrettungswesen
Schonscheidtstrasse 28, D-4300
Essen 13
F.D.R.

Director: F.J. Kock

Tremonia Experimental Mine
Versuchs-grubengesellschaft GmbH
Dortmund, West Germany

Managing Director: Mr. Berg

- f) Główny Instytut Górnictwa
(Central Mining Institute)
Kopalnia Doświadczalna "Barbara"
(Experimental Mine "Barbara")
43 - 190 Mikołów
ul. Podleska 72
Poland

Dr. Róża Cybulska

- g) Australia

The New South Wales Dept. of Industrial Relations
The Director, John Smith
The Londonderry Industrial Safety Centre
132 Londonderry Road
Londonderry, N.S.W. 2753
Australia

Tel: (Aust.) 47-77-4261

3.3 RESEARCH IN NON-CANADIAN FACILITIES

3.3.1 Introduction

The costs of conducting a Canadian research project in a non-Canadian facility (Where contractual research/testing projects are undertaken) is difficult to determine unless a specific programme or project has been defined. Guidelines for research capability and cost determination are given below.

3.3.2 U.S.B.M. - Pittsburgh Centre

The fire and explosion testing facilities at the Pittsburgh Research Centre consist of:

- . Two underground experimental mines, Bruceton and Lake Lynn, Pa.
- . Surface, flammability testing gallery.
- . Laboratory-scale testing apparatus to evaluate the characteristics of materials: ignition, burning, heat resistance and products of combustion. (See Appendix B).

The lake Lynn tunnel layout, (by means of explosion proof, moveable bulkheads), allows the following configurations to be simulated -

- . full mine circuit
- . single entry or heading
- . three parallel entries or headings
- . single entry longwall
- . three entry longwall

Details are provided in Bureau of Mines Information Circular IC8911/1983. \

Summaries of significant research results in 1986 and 1987 and the program of research for 1988 are available from USBM. Extracts from these programs, together with a list of published research data are given in Appendix B.

The staff of the Pittsburgh Research Centre comprises - 320 full-time, Professional, technical and Clerical people and 42 part-time staff.

The Centre will undertake Research on a negotiated contract basis.

Basic Personnel rates are:

. Scientists	\$23.35 US/hr	=	\$28.25 CAN/hr
. Engineers	\$23.35 US/hr	=	\$28.25 CAN/hr
. Technicians	\$13.91 US/hr	=	\$16.83 CAN/hr
. Senior Admin.	\$29.35 US/hr	=	\$35.51 CAN/hr
. Junior Admin.	\$20.60 US/hr	=	\$24.93 CAN/hr

These rates would be increased, depending on the type of work required, to cover the cost of the facilities utilized.

3.3.3 Explosion and Flame Laboratory - Buxton U.K.

The installations consist of administration, workshops/equipment housing, test areas and a concrete, instrumented tunnel for the study of Fires and explosions.

The Buxton facility is currently cooperating with similar facilities and organizations in the E.E.C. to standardize and correlate fire test specifications and results.

Recent tests have been concerned with the fire resistance of -

- . insulating materials for chilled water pipes of mine air refrigeration systems.
- . foam-fill material injected into the tires of mine rubber tired vehicles.
- . identifying fire and toxic smoke hazards presented by newly developed, industrial materials and techniques.

Health and Safety Executive, Buxton are reluctant to undertake contract work but might be persuaded to enter contracts with similar organizations in Commonwealth Countries, i.e. Labour Canada. However, they will not accept assignments at short notice and their work in progress would receive priority.

Technical personnel charges of 325 pounds sterling per day (approx. \$650 Can./day) can be expected; a typical "Fire Resistance" test costs in region of \$3,000 Can. - \$4,000 Can. Secondment of personnel to a Canadian establishment would be restricted to staff of "Section Head" status limited to durations of one to two weeks.

3.3.4 Yorkshire Regional Laboratories U.K.

These are Laboratories of the British Coal Corporation (B.C.C.) and consequently are primarily concerned with drawing up specifications and acceptance tests related to fire resistance and combustion characteristics of new materials being introduced into coal mining by B.C.C. This includes:

- . lubricants and oils
- . hydraulic fluids
- . resins and rigid foams for strata injection and sealing
- . roadway spray-on linings
- . fire proofing treatments for mine timber and other flammable materials
- . fire resistant fabrics

Materials testing contracts, in the areas outlined above, would be readily accepted at short notice. The laboratory will also negotiate contracts to train Canadian personnel to perform similar work in a Canadian testing facility. The secondment of British staff to a Canadian facility is not available at this time due to staff shortages.

Charges for personnel are:

	<u>Pounds Sterling/hr</u>	<u>Equiv. \$Can/hr</u>
Laborers	14.50	29.87
Technicians	17.50	36.05
Scientific Officer	22.00	45.32
Senior Specialist	35.00	72.01

There would be additional charges for Facility use, power and materials. A typical material test would cost from \$1,000 to \$1,500.

Other services marketed are:

- a) P.C. Programmes, on cassette or floppy disc, to determine explosibility of gas mixtures according to the Hughes/Raybould method.

This is also available as a software, microprocessor, VDU and printer package.

- b) Design and hardware to set up a mine environmental monitoring system with up to ten sampling points (based on a tube bundle system) or, alternatively, using transducer sampling heads. The package can include analyzer, computer programme, interrogation capability and presentation of CH_4 , CO and O_2 readouts, as well as air velocity, at a mine control centre at the surface or at a remote location in the mine.
- c) Sensing heads for Hydrogen and sensors for other gases are currently being developed.

3.3.5 CHERCHAR - France

Due to decreasing coal mining activities in France, CHERCHAR are turning to research programs on behalf of other industries, mainly in the field of Safety and Occupational Health. They continue to undertake investigations concerning the prevention of fires and explosions in mines but now also include, for example, the Cross-Channel Tunnel Project and special hazards in the chemical industry.

Mining projects are currently being directed towards reducing the risks of methane ignition and fire propagation. A strategy has also been developed for the protection and safe evacuation of miners during an emergency.

M. Claude Froger, Adviser to the Research Director of CHERCHAR, confirms that testing could be done on a contractual basis and suggests that they would be willing to help decide what should be the priorities. To do this they would be willing to send to Nova Scotia a mining engineer with experience of managing mine operations and who is also a member of the CHERCHAR fire committee.

No indications of costs were given and it must be assumed that these would be negotiated for particular projects.

At their research centre in Verneuil-en-Halatte CHERCHAR has an experimental fire gallery which is being used to investigate:

- . behaviour of polymer plastics in a fire;
- . behaviour of electric transformers in a fire;
- . means of protecting against hot, toxic, products of combustion;
- . the effectiveness of extinguishants; and
- . reliability and application of fire detectors.

The fire gallery consists of a 50 m horizontal gallery of a 10 m² cross-section. The entrance to the gallery can be closed by a vertical sliding door.

Half way along the gallery a special test chamber is attached. It is used for the testing of equipment designed to offer personal protection against fire generated toxic gases.

At the end of the horizontal gallery is a 10 m high vertical tower designed to permit the vertical propagation of fire to be studied and also to evaluate the quantity of toxic substances and heat emitted by fire in the horizontal section. Gases from the tower are transmitted to a fumes scrubber via a 1.8 m diameter conduit.

Exhausted fumes from the gallery and the tower pass through a dry filter chamber fitted with a recorder and through a water spray scrubber. The gases are then diluted before being emitted from an 18 m high chimney stack. Water from the scrubber is treated before being discharged into the environment.

Perhaps the CHERCHAR project of greatest interest to the Sydney Coalfield, is the testing of pressurized refuge chambers which offer protection against fumes and heat. Two types have been tested; the first consisted of tubes placed in a mine entry, cooled by compressed air or a combination of compressed air, water and insulation. The second type consists of a chamber excavated in the side of an entry and closed off at its entrance. The entrance of fumes and heat is prevented by pressurizing the chamber with compressed air.

The initial tests produced promising results and more are being projected.

In the past, CHERCHAR have conducted tests on electrical apparatus vehicles and other mechanical equipment. They have also conducted flammability tests on various types of mining materials. Their investigative work is of a high standard and internationally respected.

3.3.6 Hauptstelle - Mine Rescue Centre, Essen (FDR)

This establishment of the Ruhr coal mining district is operated by Bergbau - Forschung GmbH. It provides not only a twenty-four hour per day mine rescue service but it is also the Research and Development Institute of Steinkohlenbergbauverein (Hard-coal Mining Association).

The Centre describes its main duty as organization and improvement of mine rescue in Northrhine Westphalia.

In this context, increasing importance is assigned to preventive measures. Actual rescue missions for saving human life have become more and more rare. Activities nowadays are concentrated on prevention, early detection, and fighting of mine fires. Hauptstelle gives assistance to crew training and, in their testing laboratories, they check for reliable functioning of self-rescuers. Fire protection is assigned great importance and Hauptstelle, together with experts at the mines, continue to work on its improvement. For early detection of mine fires a network of approximately 200 CO measuring, recording, and alerting systems, with data transmission to the mine control centres on the surface, are installed.

In recent years, new methods for combatting mine fires have been introduced with Hauptstelle support; these include:

- . pressure balancing techniques
- . centralized mortar supply for stoppings
- . fire fighting by inertizing with nitrogen.

Hauptstelle provides fire prevention and fire fighting support and advice to the mines for both surface and underground operations, including coal preparation, coal handling plant and waste dumps.

In the field of development and testing of breathing apparatus for mining, Hauptstelle has acquired an international reputation. Their testing station work reaches far beyond the mining industry; breathing apparatus and diving equipment for

fire brigades are also tested here. Hauptstelle is recognized by the Federal Ministry as a competent testing authority for breathing apparatus. In cooperation with Versuchsgrubengesellschaft (experimental mine) in Dortmund, Hauptstelle does testing of fire fighting equipment for underground. The close contact with the mines and with the equipment manufacturers ensures that new ideas are put into practice quickly and any equipment deficiencies are corrected without delay.

The emergency - equipment stores include special equipment for rescuing trapped miners, e.g. the "Dahlbusch bomb" which became famous through the rescue action at the Lengede iron ore mine in 1963. There is also a highly sensitive sound locator for detection of knock signals as well as special microphones, and a highly light-sensitive TV system for establishing and maintaining communication with trapped miners.

Each year Hauptstelle puts on a large number of courses, and a fire fighting training gallery is available. There is also a "climate chamber" for research on physiological stresses which result from working in hot humid atmospheres.

More information on Hauptstelle is given in Appendix B.

Hauptstelle is under the control of a Director and has a staff consisting of:

Scientists	6
Engineers	11
Technicians/Craftsmen	6
Others	<u>17</u>
TOTAL	40

Charge-out rates for staff, including travel time, are:

<u>CATEGORY</u>	<u>DESCRIPTION</u>	<u>DM</u>	<u>EQUIV. \$ CAN/DAY</u>
A	Chief Engineer (Scientist)	1,325	874.50
B	Senior Engineer	1,120	739.20
C	Technician/Craftsmen	840	554.40

These rates include all regular office and administrative charges.

Staff levels are not, generally, sufficient to allow any commitment to major contracting work abroad and Hauptstelle cooperates closely with:

Montan - Consulting GmbH,
P.O.B. 10 32 62
D - 4300 Essen 1

Montan - Consulting can draw from a larger number engineer employees, most of them from Ruhrkohle A.G., the biggest West-German hard coal mining company. All requests for supplies and services should be addressed to Montan - Consulting. A copy of the "General terms and conditions of trade for supplies and services" is included in Appendix B together with photographs and lists of technical/research work (in German).

In addition to Hauptstelle, there is the Tremonia Experimental Mine operated by Versuchsgrubengesellschaft, GmbH in Dortmund. No specific data was obtained from this establishment however, enquiries indicated that they are mainly concerned with conducting fire resistance tests on plastics, fabrics, vee-

belts, brake linings, hydraulic fluids, strata injection resins, rigid foams and mine timber fireproofing treatments.

They also examine the interaction between mine fires and ventilation, e.g. thermal convection and ventilation reversal, throttling effects and smoke back-up.

Contract work will be undertaken, but each research/test project would be treated separately with schedules and prices arranged project by project.

3.3.7 Central Mining Institute - Poland

The problems of mine fires are dealt with by the Ventilation department under its Director, Prof. Dr. Henryk Bystron. The facility address is:

Główny Instytut Górnictwa
Zakład Aerologii Górnictwa
40-951 Katowice
Plac Gwarków 1

The facility was constructed in 1952; it has 13 scientists and 16 engineers/technicians on its staff. Current investigation and research deals with:

- . ventilation in mines
- . prediction and prevention of mine fires
- . fire suppression and extinguishment of mine fire areas
- . prevention and suppression of spontaneous heating in coal stockpiles and silos.

The facility has at its disposal the equipment, instruments, devices and capacity to deal with:

- . investigations into spontaneous combustion
- . trials with proposed ventilation schemes
- . analyses of mine gases
- . prediction of mine environment hazards.

It is worth noting that earlier Polish testing experience was related to:

- . coal dust and methane ignitions
- . effectiveness and design of rock dust and water barriers in suppressing coal dust explosions
- . application of inert rock dust as a means of preventing coal dust explosions and their self propagation.

In their response to a request for information, no comments were made regarding contract research. It is likely that such work would be undertaken at reasonable cost though each project would no doubt have to be individually negotiated with the Polish authorities.

A list of papers and research work produced by the Ventilation Department staff is given in Appendix B.

3.3.8 Australia - N.S.W.

The Londonderry Industrial Safety Centre, N.S.W., has been in operation since 1964 but new, mine fire testing galleries were constructed and put into services in 1985/86. These galleries simulate over 200m of full-size mine roadways of rectangular cross-section. Design criteria for this Fire Gallery were

discussed at the 20th Conference of the International Safety in Mines Research Institute, Sheffield (U.K.) 1983 (See Appendix B).

The gallery is constructed on the surface using a modular design to allow roadway configurations to be modified to correspond to pillar sizes between 40m and 70m. The gallery layout is primarily designed with Board and Pillar and Multiple Entry Longwall mining systems in mind. In view of this, and considering that roadways in N.S.W. are rectangular, the Londonderry galleries are: -

- . Standard height, 2.4m
- . Widths, vary between 4.8m and 5.52m.

This is significantly different from most galleries around the world which approximate to square cross-sections.

The gallery is extensively instrumented and the data fed to a computer for processing. The gallery design also recognizes the value of being able to correlate results with those obtained in other galleries.

Ventilation is by a mechanical fan which can be cooled by water sprays; it is capable of producing air velocities in excess of 3m/s (590ft/min).

The gallery design called for the tunnels to have brick and moulded refractory linings which simulate the "heat-soak" characteristics of an all-coal environment. The facility was particularly designed to conduct investigations into early fire detection, rate of fire-spread and the effects of fire on the ventilation.

The Londonderry Centre carries out flammability and fire resistance testing for industry in general - as well as for coal mining. In the past they have done work on:

- . explosibility of methane/coal dust mixtures;
- . explosion suppression and barriers;
- . flame lamp safety (in connection with the Maura Mine explosion).

In addition to the new, full-size galleries, there are also small cross-section galleries available for testing work.

The Director of the Centre, John Smith, was contacted by phone. He explained that some of the current work is being done on small-scale fire testing of materials, mainly to determine rates of burning and heat generation. These tests are related to studies of fires in larger, full-size roadways to determine the effects of heat and hot smoke on ventilation. The investigations are directed towards computer aided prediction of fire behaviour, the control of fire spread and their effect on ventilation and evacuation options.

It was pointed out that the Londonderry full-size galleries were designed for fire studies, they are not suitable for explosion testing. The Londonderry staff had resorted to the use of Test Tunnels in China for large scale explosion testing.

Mr. Smith said that the Londonderry Centre would welcome contractual research work into fires, combustion and fire/ventilation problems. He pointed out that scheduling of the work would depend on availability of the facilities and staff. At the moment the Centre is short of staff and would

welcome the participation of Canadian personnel on Canadian contracted projects.

Contract costs would have to be determined according to the nature of the project. Normally cost would be based on: -

- . A charge for facility use
- . Labour costs and
- . An overhead cost.

4.0 RESEARCH AND DEVELOPMENT RELATED TO SYDNEY
 COALFIELD
4.1 INTRODUCTION

The basic protective measures against the ravages of mine fires are:

- . their prevention,
- . their detection,
- . their combat,
- . escape from,
- . their containment and extinguishment.

These actions are common to all mine fires and Research and Investigation Programmes address the many aspects of some or all of these areas. The result is that all the research into mine fires and explosions, being carried out in all mine fire research programmes is relevant, in some degree, to the CBDC mining operations. The results of most of this research are available as published material or can be acquired by modest payments or by sharing in the research costs.

It is clear that non-Canadian research establishments have developed facilities, techniques and staff to an advanced technical level; there is little point in duplicating this research and testing capacity in Cape Breton, especially since there are research centres willing to carry out research and/or testing, contractually.

4.2 SPECIAL NEEDS OF THE SYDNEY COALFIELD MINES

4.2.1 General

The special needs of the Sydney Coalfield mines at this time, were noted in the Stage 2 report; they were:

- a) Improved installation and operating standards for conveyors and electrical equipment.
- b) Improved designs and use of non-flammable materials related to mine ventilation and support.
- c) Improved emergency evacuation facilities up the main slopes in case of mine fire.
- d) Improved fire fighting training.

4.2.2 Fire Prevention

The first two items (a) and (b) are particularly important, being related to Fire Prevention. Action to bring about improvements will come from CBDC management and engineering staff. They have already shown their ability to keep up-to-date with new technology and demonstrate a readiness to use newly developed methods. No requirements for special research projects were noted in this area.

For item (b), "Improved designs and use of non-flammable materials related to ventilation and support"; again, most of the work will be done by CBDC technical staff as part of their normal duties. In fact, some of this work is already underway, as is mentioned in Stage 2 of this report, and no special research is necessary.

4.2.3 Emergency Evacuation

Improved emergency evacuation facilities up the main slopes in the event of a mine fire (item c) is another case where the CBDC engineering staff has the capability to bring about improvements using existing technology; research is not required.

Suggestions for improvement were made in Stage 2 and included:

- . Establishing radio communication between the man-riding cars and the hoistman. CBDC has already started to do this.
- . Improving the capability of reversing the air flow in the conveyor intake slope using doors remotely operated from the surface control room.
- . Examine the possibilities of increasing the hauling speed of the man-trip and of using sealed man-trip cars which would enable the occupants to be carried safely through a hot, smoke filled atmosphere.
- . Improving the means of isolating the slopes from each other, particularly intakes and returns, to prevent heat and smoke from one slope entering another and rendering it unavailable for escape.

4.3 PUMP PACKING

4.3.1 Application

In CBDC mines, pump-packing and the materials used for pump-packing are becoming increasingly important.

The material is a gypsum/anhydrite type compound which can be used to:

- a) Build solid roadside pack supports in place of the usual, combustible, wood cribs used on the advancing longwalls.

- b) Build roadside packs on retreat longwalls, which will probably soon become the preferred mining method in the Sydney Coalfield mines.
- c) Construct fireproof seals and stoppings quickly.

At present, the material used in CBDC is imported from U.K. in considerable quantity. However, there are mineral deposits in Cape Breton that might enable a similar, acceptable product, to be manufactured at or near to, the mines.

4.3.2 Local Production of Pump-Packing Material

It is understood that CBDC has taken a preliminary look at the feasibility of locally producing pump-pack material but real technical progress probably requires sustained effort and direction by a small group assigned to oversee this specific task. CANMET could well act as a catalyst in bringing this about.

The group might include personnel from CBDC, N.S. Mines and Energy and CANMET. A source of funding would be necessary to enable the group to arrange for investigations into:

- . Sources of mineral, its quality and availability;
- . Constraints imposed by Patents held by existing suppliers;
- . Mineral treatment and chemistry to obtain a suitable product;
- . Testing of laboratory prepared samples; and
- . Economics of full scale production.

The work might be undertaken by CBDC/CANMET or be assigned to Canadian Consultants.

4.3.3 Research and Testing of Pump-Packing Material

Research and testing programmes, leading to the development of local pump-packing material, would include mineral treatment, chemical processes and laboratory strength testing. Such a programme lends itself to contractual research in Canadian facilities.

4.4 FIRE FIGHTING TRAINING - CBDC

In recent years the quantity of fire fighting equipment and devices for combatting and controlling fires (together with quality control inspections and maintenance of the equipment) has increased to a high level in the CBDC mines (in comparison to many other mines and industrial undertakings). Further expansion in this area would not significantly increase safety.

Stage II of this report strongly recommended that efforts now be directed toward the ability to prevent and combat fire through improved fire fighting training. This will help in three ways:

- . It will help ensure that the equipment provided will be used effectively;
- . It will provide the man-on-the-job with the skills and knowledge necessary to deal with fires while they are still in the initial stages;
- . It will inculcate a better appreciation of the causes of fires and a greater acceptance of responsibility for day-to-day fire prevention on the part of underground employees both as individuals and collectively.

4.5 SUMMARY AND CONCLUSIONS
4.5.1 Research and Development

From this brief review of the Sydney Coalfield needs and considering the work being undertaken in non-Canadian research facilities, it is clear that, at this time, no specific research project in a foreign facility is necessary.

The European Laboratories are now conducting flammability tests on a wide variety of materials, not so much to research their flame resistant properties but to correlate standard testing procedures, specifications and acceptance standards between EEC countries. This leaves some of them with reduced capacity for contractual research work.

Research into local production of pump-packing materials is recommended. The formation of a small directive group to pursue this project is proposed.

No specific mine fire research needs are identified that should be carried out contractually in non-Canadian establishments. If research needs are identified in the future, the USBM Pittsburgh Research Centre offers a wide range of services, including full scale mine galleries.

In terms of geographic proximity, willingness to accept contractual research, and scope of facilities, the Pittsburgh Research Centre appears to be an obvious choice if research is needed. Other factors favouring this choice would be:

- . english is the working language;
- . the facilities are probably the most extensive in the world; and
- . a tradition of cooperation has been established between USBM, CANMET and CBDC.

The work and facilities of the Australian, Londonderry Centre, N.S.W. concerning the interaction of mine fires and ventilation should also be kept in mind. Their willingness to cooperate and work with Canadian personnel with English as the working language are obvious advantages.

4.5.2 Fire Fighting Training Facility

The means to combat fire is adequately provided for in the CBDC mines. Now, efforts should be concentrated on fire prevention. Fire prevention should be intensified in two areas:

- . technical installation and operational improvements.
- . improved worker participation in fire prevention through training.

A need for Fire Fighting Training in which near realistic fire fighting experience and endurance can be gained was identified in Stage II. The objectives of the training would be to:

- . improve fire fighting skills at all stages of mine fire combat;
- . develop attitudes of commitment to fire prevention through increased knowledge; and
- . improve abilities to detect fire at an early stage and take appropriate action.

In Stage II the facilities needed for this training were discussed and it was recognized that there were two main choices:

- . Use the real, actual, working places in the mines complemented by surface classroom/practice facilities.
- . Construct a special fire training gallery in which realistic conditions can be simulated and which incorporates classroom and surface practice facilities.

This gallery would be a single facility used by all CBDC mines. There are arguments to be made both for and against these choices but the cost of constructing and operating a special central Training Facility is obviously a major factor.

The decision as to which course to adopt is to be made by CBDC. To help them make this decision, the design and capital and operating costs, of a suggested fire training facility are given in Section 5.0 following.

5.0 FIRE TRAINING FACILITY

5.1 INTRODUCTORY COMMENTS

The selection of a site for a fire training facility has not been dealt with detail but following discussions with CBDC Engineering staff, a location near the Phalen mine would probably be available. There is ample space in this area on CBDC property and it has the following advantages:

- a) It is easy for electric power to be supplied from the mine.
- b) It is conveniently situated for use by both the Phalen and the Lingan Mines which are the two largest of CBDC's three mines.
- c) Costs can be minimised by trainees using the bathing and washing facilities at the mines instead of providing these at the training gallery.
- d) There are no construction constraints and the ground presents no unusual difficulties of stability and drainage.

5.3 PROPOSED DESIGN

5.3.1 General Layout

The general arrangement of the proposed design for the Fire Training Facility is shown on drawing 5.1 and attached as Appendix D.

The facility is in three sections:

- . The outdoor practice area.
- . The indoor area.
- . The mine simulation area.

5.3.2 The Outdoor Practice Area

This area measures 20.0m x 24.0m; it has a firm gravel floor and is surrounded by a 3.0m high security fence.

At one end of the Practice Area are mounted three, underground type, hydrant/hose stations. At the other end are arranged five fire sites, each one designed to contain practice fires without danger to adjacent structures. The following drawing, Fig. 5.2, shows the outside Wet Drill Practice Area and the proposed structures in which mine fires can be simulated and where their extinguishment can be practiced in realistic surroundings.

The floor of the fire areas are graded towards a drainage channel to avoid the accumulations of water. The walls of the structures (shown as concrete) may be either brick, cement block or pre-cast concrete panels; the intention is to provide a non-flammable, permanent shell. It is expected that the proposed structures will allow outside practices to be conducted almost year round except in the very worst of weather.

5.3.3 The Indoor Area

The indoor area is in two parts each of which will be a steel frame, metal clad construction made up of standard pre-fabricated sections erected on a concrete pad base. The first part is located adjacent to the outside wet practice area. It is 10.0m wide and 24.0m long. At one end there is an Instruction Room big enough to accommodate comfortably about 20 trainees and an instructor. Draw down blinds or shutters are necessary to enable the room to be darkened for showing films, slides and overheads. There will also be a chalkboard and pull-down projector screen.

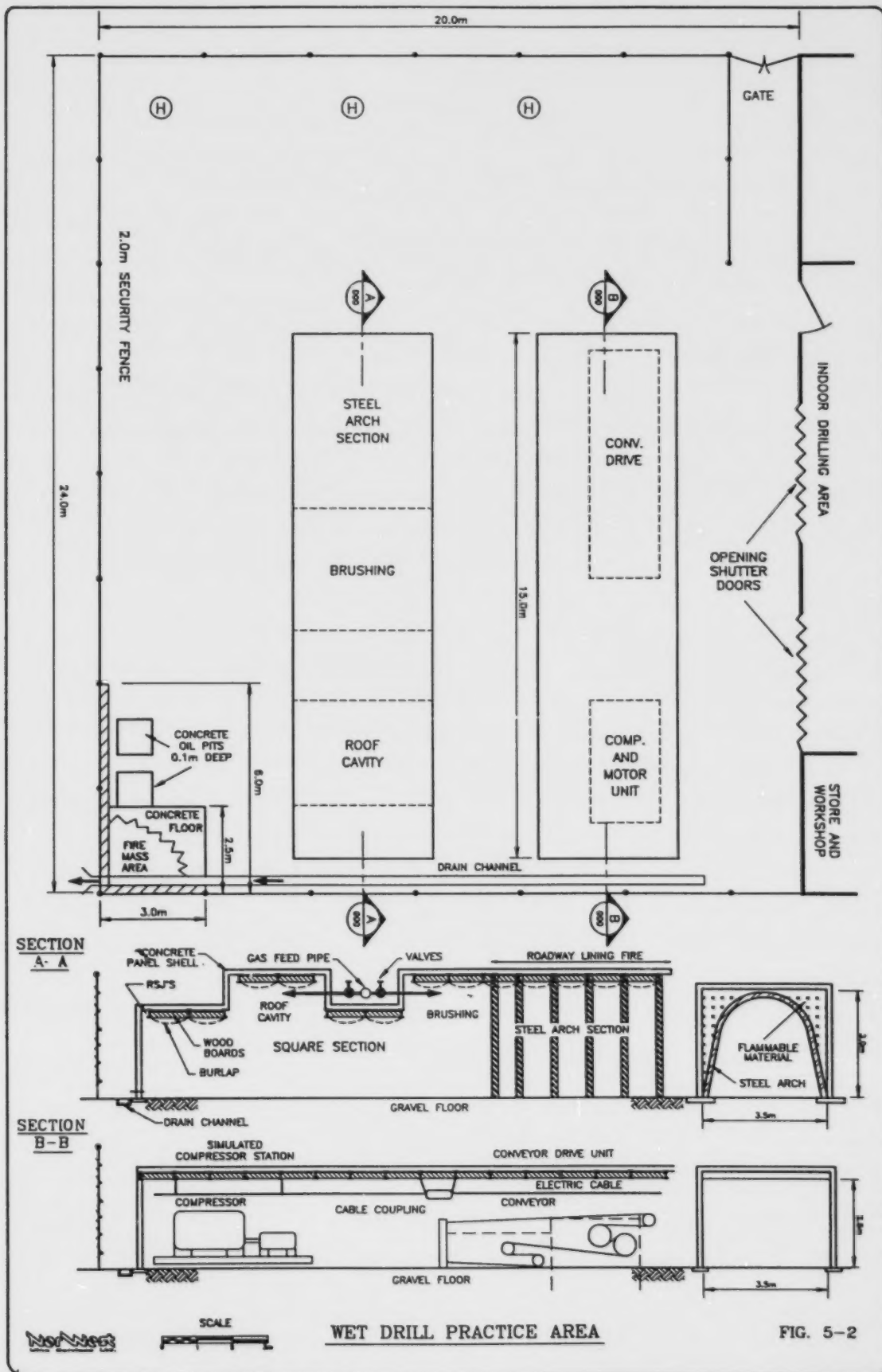


FIG. 5-2

At the opposite end of this first indoor part is a 4m x 10m store room and workshop fitted up for filling CO₂ and dry-chemical extinguishers and for carrying out simple minor repairs to fire fighting equipment.

Between the instruction room and the workshop there is a large 14m x 10m Indoor Drill Area with a hydrant/hose station. This area too is provided with a chalkboard and display panels for charts and illustrations. Large folding or roll-up doors open up this area to the outside practice yard.

The purpose of the indoor practice area is to provide space for early stages of training and to provide an alternative practice space if the weather is too severe for outside practices. The big doors offer space and better light and ventilation during warm weather. This indoor drill area will be utilitarian with open ceiling and bare concrete floor; the metal cladding will be insulated.

The second part of the indoor area is primarily devoted to administration and services. There is a washroom which includes three showers (for staff only) and a drying room for staff lockers and cloths drying. There is office space for instructors and the head of Fire Training. Central to the indoor area is the utilities room housing hot water heaters and central heating apparatus. Flanking this is a janitor's room and a medical room for first aid. A control room houses the switches, controls and communication centre for the whole facility.

5.3.4 The Mine Simulation Area

This area is mounted on a concrete pad and constructed of pre-cast concrete panels. There is an upper and a lower section joined by two, side-by-side, inclined passageways referred to as the "up-slope" and the "down-slope" on the drawings.

The upper section consists of a series of three chambers separated by metal doors. Two of those chambers are actually the top end of the inclined passageways; the third chamber acts as a 'plenum' and has a large reversible fan at one end which can either discharge to or draw from, the outside.

Below the three upper chambers is a "Hot and Humid Room" in which the heat and humidity can be adjusted to simulate fire conditions. Details of the construction and equipping of this room are given in Appendix 'C'. Alongside the 'hot' room is an Observation Corridor with windows enabling instructors to observe persons training in the hot room and watch for any indications of distress in the trainees. At the end of the Observation corridor the hot room controls are located as well as some storage space.

Next to the 'hot room' is a simulated portion of a longwall. It is assumed that this 12.0m length of face will be fitted up with hydraulic face supports and chain conveyor and that the wall of the 'hot room' will be treated to simulate a coal face. The face equipment is not required to be 'active' and is assumed to consist of worn-out parts withdrawn from the mines. Behind the face supports is a wedge shaped void formed by the floors of the two inclined 'slopes'. This void simulates the 'gob' or 'goaf' of the longwall.

At each end of the longwall is a level gate, a conveyor gate and a tail gate. These two gates connect with the bottoms of the two slopes via a 'cross-cut'.

The conveyor gate extends 10m past the cross-cut to form a "dead-end heading" at the face of which there is a sump and small pump for drainage. Here a disused conveyor drive unit may be mounted to add realism and typical mining obstacles to enhance the simulation.

In the tail gate a place is provided where an underground switch room can be mounted.

All these passageways will be fitted with typical mine supports and given the surroundings and environment of an underground coal mine as realistically as can be reproduced.

At the junction of the conveyor road and the face, iron rung ladders provide access to the Plenum chamber above through steel doors. There are also steel doors located in the cross-cut between the slopes and the gates. The conveyor gate, the tail gate and the top of the Down Slope all have steel doors which open to the outside. Variations of ventilation air flows through the simulated mine passages are possible by the opening or closing of doors and changing the direction of the fan. These variations are shown diagrammatically in Figure 5.3, details of the fan are given in Appendix C.

5.4 AUXILIARY EQUIPMENT AND SERVICES

5.4.1 Communications

The facility will be connected to the regular telephone services with phones in the medical room, the instructor's room and the office of the facility chief.

In addition to the regular phone service there will be mine type communication services and alarms all connected to the Gallery Control Centre. Emergency pull wires will be installed in all the 'mine' practice areas. There will be a loudspeaker and signal bell system throughout the galleries with microphones in the gallery control centre and the 'hot/humid' control room. There will also be provision for relaying mine and fire sounds, from pre-recorded tapes, over speaker units. In the face section, in the two gates and at the cross-cut, there will be mine-type telephones. Locations of communication devices are shown in Figure 5.4.

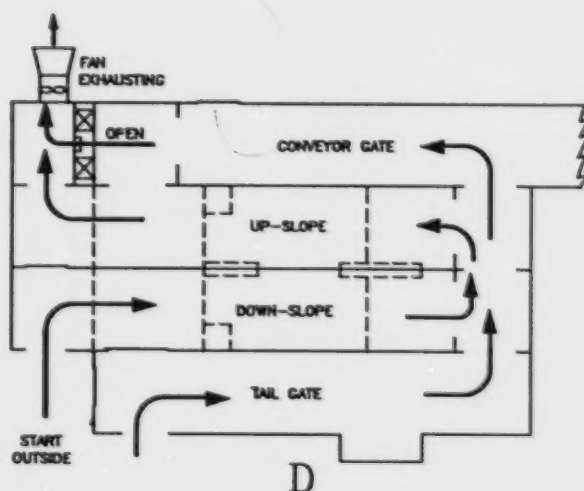
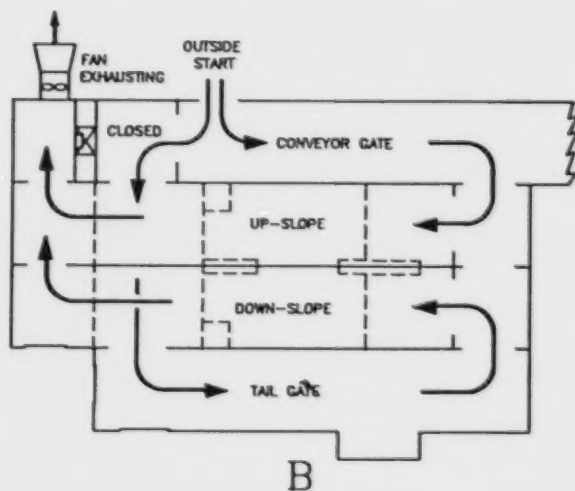
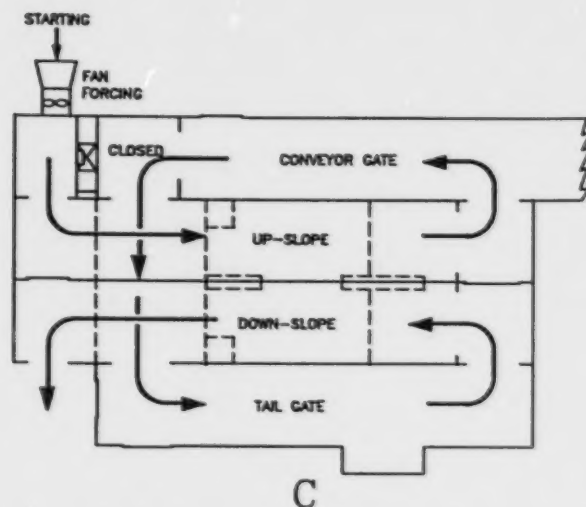
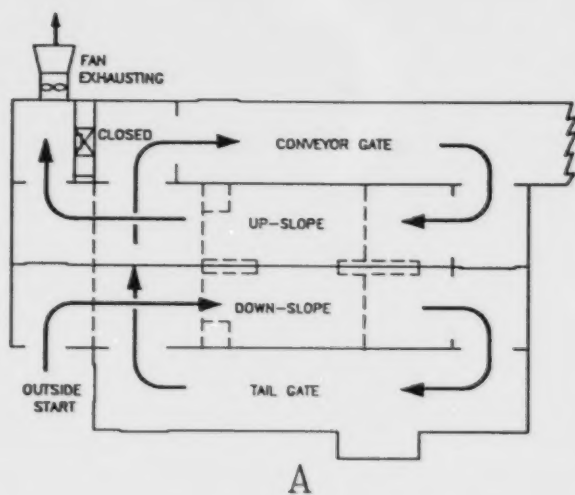
5.4.2 Lighting and Heating

(a) Lighting

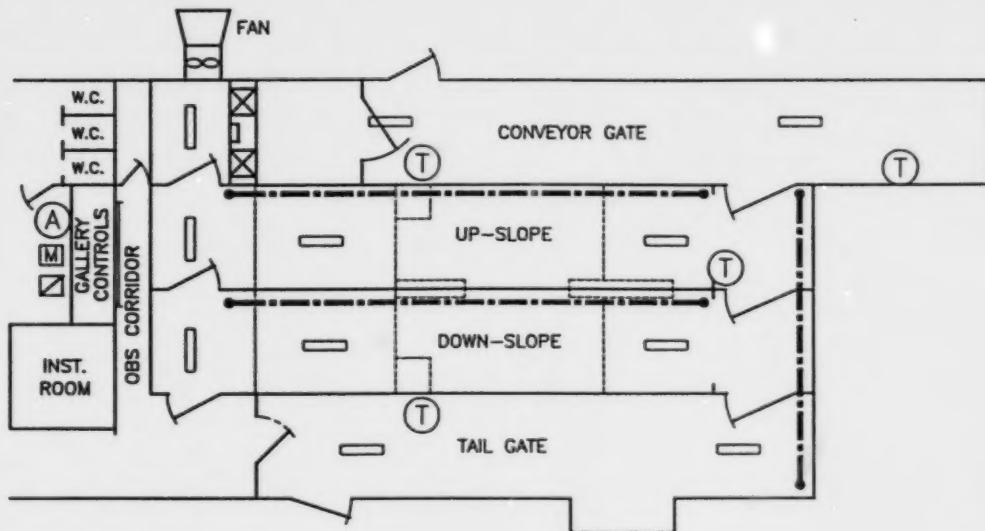
Lighting in the indoor section will be typical for industrial/office environments. Lighting in the 'mine' will include industrial type fluorescent lamps in the two slopes and gates, and typical F.L.P. lamps on the face and road heads, (see Fig. 5.4).

(b) Heating

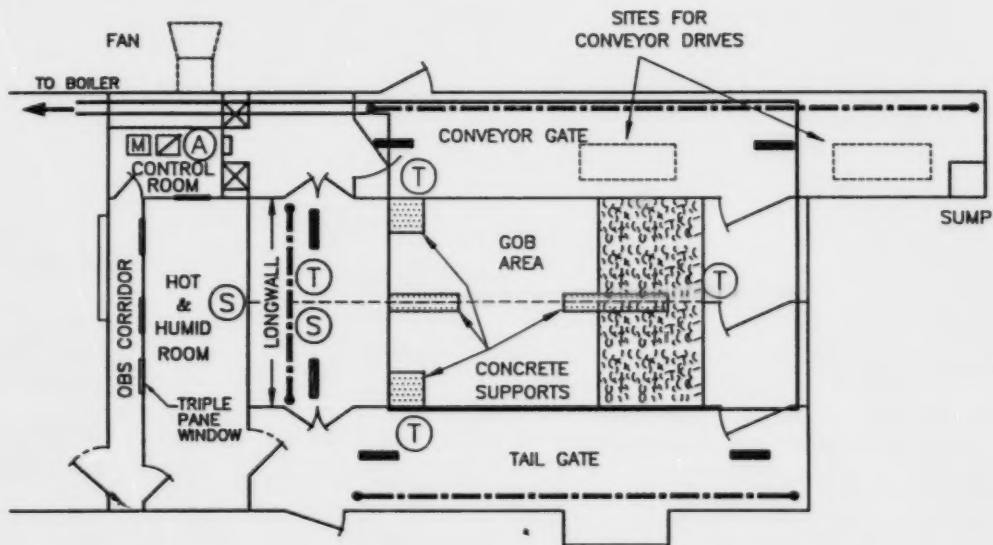
A hot water and central heating plant is located at the centre of the 'indoor block'. It is envisaged that this will be fuelled by propane or fuel oil. Heating in the indoor block might be by forced air heating or electric baseboard heaters. A boiler will provide hot water for washing and for a hot water pipe heating system in the 'mine'. It is not necessary to bring the galleries up to room temperature but is desirable to maintain a tolerable temperature during the winter. When the main fan is used to circulate air during exercises much of the heat will be lost, especially during the winter months, however, this will not be a prolonged condition. It was not believed necessary to provide a heater at the fan for such intermittent use.



ALTERNATIVE VENTILATION CIRCUITS



FLOOR PLAN - UPPER FLOOR



FLOOR PLAN - GROUND FLOOR

LEGEND

EMERGENCY PULL-WIRE	---	ALARM BELL	(A)
FLUORESCENT LIGHT (INDUSTRIAL)	▭	LIGHT SWITCHES	⊠
FLUORESCENT LIGHT (FLP)	—	MINE TELEPHONE	(T)
80mm DIAM. HOT WATER PIPES	—	LOUDSPEAKER/MIKE TELEX	(M)
LOUDSPEAKER & SIGNAL BELL	(S)		

COMMUNICATION, HEATING AND LIGHTING

5.4.3 Utility Services

The facility must have services of:

- . Electricity, 110v normally but a 500v supply will be required for the main fan.
- . Portable Water Supply. The gallery site is not fixed but it is assumed that it would be close enough to the Phalen mine to allow water to be piped over.
- . Sewage and waste water disposal. It is assumed that the facility would have its own septic tank for sewage. Fire fighting water would probably be drained off to ground soak without treatment.
- . Fire Fighting water, it is assumed, would be piped in from the main fire fighting water storage facilities at the Phalen Mine.

5.4.4 Ancillary Equipment

(a) Smoke Generators (See Appendix 'C')

Smoke generators would be of the type used by City fire departments and entertainment establishments such as theaters. The smoke is -

- . non-toxic, non-irritant and non-contaminating;
- . non-flammable;
- . can be distributed through pipes and ducts;
- . is dense and white.

The generators require a domestic electrical supply and can be operated by remote control. It is convenient for the 'mine' galleries to have domestic, weather proof, 110v outlets at a few convenient locations.

(b) Carbon Dioxide Charging Panel (See Appendix 'C')

This unit is used for re-charging CO₂ extinguishers and is an essential piece of equipment unless there is already a recharging station with capacity to handle the high recharging demand of the Training Facility.

It is possible that the Fire Training Facility could become a central extinguisher recharge and service centre for all CBDC operations. It might be a revenue earner if this service was extended to the public however its location might not be convenient enough to do this successfully. It is assumed in this report that the facility would service its own extinguishers, that it will have a CO₂ charging panel and a small 100cfm/100psi compressor to operate the charger.

(c) Cap Lamp Chargers

These are not provided; it is assumed that instructors and trainees would pick up lamps at the Phalen Colliery lamp room.

Exclusions

The estimated construction cost does not include the costs of equipment, furnishings, sound and communications equipment, wallface and underground simulations (arching, blocking, conveyor drive, etc.).

5.5 CAPITAL COST ESTIMATES

5.5.1 Main Structure

The cost of the main structure was estimated by both Norwest and by CBDC Civil Engineers; the two estimates were within 5.5% of each other. It was decided to adopt the CBDC estimate since it was carried out by people familiar with the location and local costs.

The building costs assume a pre-cast concrete panel construction and estimates are given to a Class 'B' level of accuracy. Details of the costs are given in Table 5.1; they do not include mine simulation or mine equipment.

All costs, capital, additional and operating, are given as 1988 Canadian dollars.

5.5.2 Additional Capital

There will obviously be a need to construct some access and parking, and mount signposting and exterior lighting. It is anticipated that a motor vehicle would be assigned to the facility staff for making visits to the Lingan and Prince mines as well as for picking up materials and lamps, etc. from the mine. An accurate assessment of the capital cost of these features is not possible when a final site has not been selected, however the following estimate is given:

<u>Item</u>	<u>\$</u>
Graveled access road and parking 1,500m ² @ \$26/m ²	39,000
Sign posting	1,300
Lighting	1,000
Motor Vehicle	24,000

	65,300

TABLE 5.1

FIRE FIGHTING TRAINING GALLERY
MAIN STRUCTURE - CAPITAL COST

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>COST (1988 \$)</u>
1.	Earthworks c/w excavation, site grading, granular fill	\$ 55,000
2.	Reinforced concrete	\$250,000
3.	Concrete insulated pre-cast wall elevated slab construction	\$450,000
4.	Structural Steel, decking & single ply roofing	\$274,000
5.	Interior masonry partitions	\$ 25,000
6.	Interior flooring, ceiling	\$ 34,000
7.	Interior paintin	\$ 12,000
8.	Interior finishes, i.e. fire curtain, washroom facilities, finish trim, etc.	\$ 20,000
9.	Fire protection (sprinkler & alarm) panel	\$ 45,000
10.	Fencing	\$ 5,000
11.	U/g piping (water, drainage)	\$ 24,000
12.	Surface Bldg. piping, hose stations, hydrants, fixtures, hot water	\$ 90,000
13.	Doors, gla2ing	\$ 65,000
14.	Electrical lighting, heating, humifiers, power including services connection	\$160,000
15.	Air distribution (Supply & Exhaust)	\$ 65,000
16.	Misc. metal & Fabrications	\$ 15,000
17.	Engineering Costs at 6%	\$ 95,000
18.	Contingency funding at 10%	\$168,000
Total		<u>\$1,848,000</u>

5.5.3 Furnishings and Fittings

This includes all furnishing items such as desks, cupboards/cabinets, projectors, notice boards, medical room and administrative items. Details are given in Appendix C. Costs are based on Catalogue list prices; no Provincial Sales tax is included.

5.5.4 Training Equipment and Initial Supplies

This includes hand tools, hoses, extinguishers, didactic items such as films and slides, and protective clothing. Details are given in Appendix C. Costs are based on a combination of quotes and estimates. No Provincial Sales Taxes are included.

5.5.5 Total Capital Cost

The final, total, Capital cost estimate is shown in Table 5.2 following. It consists of the main structures and parking, furnishings and fittings and the initial training equipment and supplies needed for start-up; the total is \$2,118,800 excluding Federal, Provincial and Municipal Taxes.

TABLE 5.2
FIRE FIGHTING TRAINING GALLERY
SUMMARY OF CAPITAL COSTS

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>\$</u>
	Main Structure (Includes 10% Contingency)	1,848,000
	Additional: - access, parking, vehicle	<u>65,300</u>
	SUB TOTAL	<u>1,913,300</u>
<u>Furnishings & Fittings</u>		
(a)	Entrance Hall	1,807
(b)	Medical Room	5,000
(c)	Washroom and Dry	1,000
(d)	Control Room	5,670
(e)	Instruction Room	8,770
(f)	Inside Drill Area	4,190
(g)	Instructor's Office	5,290
(h)	Chief's Office	5,050
(i)	Reception Area	7,343
(j)	Janitor's Room	1,390
(k)	Stone and Workshop	18,590
(l)	Outside Practice Yard	42,000
(m)	Hot and Humid Chamber	6,300
(n)	Mine Galleries	<u>45,000</u>
	SUB TOTAL	157,400
	ADD 5% CONTINGENCY	<u>8,300</u>
		<u>165,700</u>
	TRAINING EQUIPMENT AND INITIAL SUPPLIES	37,900
	ADD 5% CONTINGENCY	<u>1,900</u>
		<u>39,800</u>
	<u>TOTAL ESTIMATED CAPITAL COST:</u>	<u>\$2,118,800</u>

5.6 OPERATING COSTS

5.6.1 Labour

It is estimated that labour costs for the gallery operation will consist of salaries and a payroll burden of 30%; no overtime should be necessary.

It is assumed that a Facility Manager would be in attendance part time who would have other duties in the Safety and Training organization of CBDC. Only 15% of the Manager's annual salary is therefore charged to the Operation of the facility.

There would be a Chief Instructor to conduct the day to day affairs of the facility and implement the Manager's training and operating policies. He will undertake the following duties:

- . Supervise the activities of Instructors assigned to the facility.
- . Maintain records of training.
- . Maintain records of expenditures and consumption of materials.
- . Maintain adequate supplies of materials; requisition supplies; keep abreast of new products and technical developments.
- . Help design training and testing programmes.
- . Participate in fire investigations.
- . Maintain technical literature and statistics of fire and disseminate information throughout CBDC operations.
- . Organize and supervise operation, maintenance and cleaning of the facility.
- . Carry out general administrative duties.
- . Make regular visits to the working places of the operating mines.

There would be two full-time instructors, one a Senior Instructor. They would be assisted from time to time by the fire officers from the three mines when persons from their mines are undergoing training. The people from the mines are not charged to the facility operations.

There would also be two labourers full-time. Their work would be:

- . Preparing fire sites for training, - supervised/aided by instructors.
- . Minor maintenance jobs.
- . Gallery clean-up after practices, - supervised/aided by instructors.
- . Daily janitorial work.
- . Recharging of extinguishers.

There would also be a full-time secretary/receptionist. Labour costs are summarized in Table 5.3.

TABLE 5.3

<u>LABOUR COSTS</u>	<u>ANNUAL BASIC SALARY COST \$</u>
Facility Manager (15% of Annual Salary)	7,500
Chief Instructor	45,000
Senior Instructor	38,000
Instructor	35,000
2 Labourers	44,000
Typist Receptionist	25,000

TOTAL ANNUAL BASIC SALARY	\$194,500
ADD PAYROLL BURDEN OF 30%	58,350
<u>TOTAL LABOUR COST</u>	<u>\$252,850</u>

5.6.2 Materials and Services Costs\$ Yearlya) Power and light:

Electricity cost	1,200
Gas (Propane - Butane)	300
Fuel, oil and Gasoline	3,000

	\$4,500

b) Materials - Consumable/replacements

	Annual Cost		\$1,000's.		
	Yr 1.	Yr 2.	Yr 3.	Yr 4.	Yr 5.
Training Materials	8.0	8.0	7.0	6.0	6.0
Cleaning Materials	0.5	0.5	0.5	0.5	0.5
Protective Clothing	1.0	1.2	1.3	1.5	1.5
Construction Materials	0.8	0.6	0.5	0.5	0.5
Hardware and Spares	5.2	4.0	3.5	3.2	3.2
Miscellaneous	5.0	4.0	4.0	3.0	3.0
	20.5	18.3	16.8	14.7	14.7

c) Maintenance & Repairs

Galleries and Structures	5.0	2.0	4.0	6.0	8.0
Vehicle	0.7	0.8	1.0	1.3	1.4
Contract repairs/ maintenance	1.0	1.5	3.0	3.5	4.0
	6.7	4.3	8.0	10.8	13.4

d) Administration

Stationary + Supplies	5.0	3.0	2.0	2.0	2.0
Telephone + Comm.	3.0	2.5	2.0	2.0	2.0
Licences, Permits, Ins.	0.5	0.5	0.5	0.5	0.5
Competitions, Pres., Expenses,	9.4	8.5	7.5	6.5	5.7
	17.9	14.5	12.0	11.0	10.2

e) Description (Annual)

<u>ITEM</u>	<u>\$</u>
Buildings and Structures (30 yrs)	61,600
Vehicle	4,800
Furnishings and Fittings (8 yrs)	20,700
	\$87,100

f) No taxes have been assigned to operating costs since they will be assessed along with the other mine buildings. It is expected that 90% of purchases will be exempt from Federal Sales Tax; that the 10% Provincial Health Service Sales Tax will apply, but not the Non-Renewable Resource Tax because the facility is not devoted to actual mining. Municipal Taxes will apply and these are expected to be in the region of:

. Municipal Tax; \$4.00/\$100 assessment Value	
Possibly up to	\$84,000
Less, Provincial re-fund of approx.	<u>\$40,000</u>
Estimate of Annual Municipal Tax.	<u>\$44,000 p.a.</u>
. Business Occupancy Tax per yr. (if req'd)	\$13,500 p.a.

5.6.3 Summary of Operating Costs

This summary is for a period of five years following start up. It shows the labour requirement the same for the whole period; it is assumed that extra help for practices will be supplied by fire officers from the mines. This will keep the permanent staff cost to a minimum; it will keep the mine's staff involved to form part of their training.

Some cost items are seen as being higher in the early years and reducing to a steady level by year five. Other costs are expected to increase to a steady level at year five as the facility use increases.

A summary of the five years operating cost estimates is given in Table 5.4. A contingency of 7% has been applied and with this, an accuracy of plus or minus 10% can be expected.

In the first year of operations, costs are estimated to be \$416,820, falling to a steady \$409,540 by the end of year five,

TABLE 5.4

SUMMARY OF OPERATING COSTS

<u>ITEM</u>	<u>OPERATING COST \$1000'S</u>				
	<u>Yr 1.</u>	<u>Yr 2.</u>	<u>Yr 3.</u>	<u>Yr 4.</u>	<u>Yr 5.</u>
Labour (Incl. Payroll Burden)	252.85	252.85	252.85	252.85	252.85
Power and light	4.50	4.50	4.50	4.50	4.50
Materials - Consumables/ Replacements	20.50	18.30	16.80	14.70	14.70
Maintenance and Repairs	6.70	4.30	8.00	10.80	13.40
Administration	17.90	14.50	12.00	11.00	10.20
Depreciation	87.10	87.10	87.10	87.10	87.10
	-----	-----	-----	-----	-----
	389.55	381.55	381.25	380.95	382.75
ADD 7% CONTINGENCY	27.27	26.70	26.69	26.67	26.79
TOTAL OPERATING COST \$	416.82	408.25	407.94	407.62	409.54

6.0 FIRE TRAINING - SYLLABUS AND PROGRAMME

6.1 FIRE TRAINING PROGRAMME

The "Fire Training Syllabus and Programme" (Table 6-1) was first presented to the Management Committee during the November '88 meeting in Sydney. It has since been discussed with several Senior Mines Rescue Officers of British Coal and they all considered the programme appropriate and comprehensive. However, two amendments are suggested as a result of these discussions, they are that:

- a) The frequency of re-training (Refresher Courses) for Senior Management should be increased from once every 4 years to once every 3 years or if possible, 2 years;
- b) Training should include the Mines Rescue Officers and Mine Fire Officers special one day courses would be attended, once per year. Also, certain mine workers who play a key role in fire prevention and fire fighting would receive special training; this would include:

- . Supervisors
- . Locomotive drivers.
- . Rope haulage operators.
- . Conveyor Belt cleaners, patrol men, and attendants.

Within the general training programmes special attention should be given to responsibilities, duties, and fire fighting functions of all levels of personnel.

6.2 METHOD OF FIRE TRAINING

6.2.1 Dry and Wet Practices

The principal use of all the galleries, longwall and the hot and humid chamber will be for DRY practices. This could include:

- . Receiving telephone instruction
- . Reading fire fighting plans
- . Searching and examining for concealed fires
- . Attacking fires
- . Control of airflows at a fire site
- . Application and deployment of extinguishing equipment
- . Hose drills past obstacles, such as ventilation doors
- . Team communication and cooperation
- . Incident reporting (written and telephone)
- . Incident investigations and follow-up
- . Search for and treatment of burn victims
- . Travelling in smoke and darkness.
- . Evacuation procedures.

6.2.2 Hose and Extinguisher Drills

Wet drills would take the form of the operational use of hoses and all types of extinguishers in the simulated mine airways. There is also provision to practice fire extinguishment of gas in roof cavities and burning oil and noxious materials. The open area with several hydrants provides for competition and timed trials, coupling of hoses, running out hoses over/under obstacles and directing water jet on targets.

For all this work, water will drain off the sloped surface into a ditch or channel; there is no danger from smoke or flame since the sections are in the open. Water proof and protective clothing should be worn.

6.2.3 Fires in the Galleries

The use of live fire in the galleries must be kept to a minimum and if used, only small amounts of non-noxious flammable materials would be used and even then, only under ventilated conditions (i.e. with fan running).

The purpose is to train Firefighters without breathing apparatus not Rescue man wearing Draeger sets.

Even small fires in confined spaces can quickly generate lethal amounts of CO and other toxic fumes. Large fires in the gallery could quickly get of control. Such fires could also create considerable damage. To have fire trainees become the victims of fire, and the fire training gallery to require the services of the local Fire Brigade would be, to say the least, embarrassing.

The smoke generator is a very useful training aid which creates very realistic smoke conditions. The Trainees should be trained to properly prepare when confronted by real fire smoke, and to call for Rescue Teams if the smoke is expected to contain toxic fumes and carbon monoxide.

6.2.4 The Use of Extinguishers in the Gallery

Dry powder and CO₂ extinguishers may be used freely in the gallery; foam and small hoses can be used but very sparingly. Large diameter fire hoses with water should NEVER be used, the facility design does not cater for large water volumes.

The Galleries will require cleaning up and drying out from time to time and a sump and pump are provided for this.

6.3 THE USE OF THE HOT AND HUMID CHAMBER

This chamber is for special practices - experience of fire conditions, acclimatization etc. but more usually as part of a traverse route in the gallery. The fire fighting team traverses the longwall, enters the Chamber, performs some work duties, then retraces its steps through the Gallery; all under close observation.

6.4 FLICKER LIGHTS AND MINE SOUND SIMULATION

Electric, red glow, light units can easily be made and, by incorporating flickering devices, can be made to simulate the appearance of fire very realistically. Used in conjunction with smoke generators a real fire effect is convincing. The units are hidden under belts or piles of lumber to create the appearance of burning material.

Sound effects add greatly to reality and can effectively simulate the difficulties of communication.

6.5 EXAMPLES OF FIRE TRAINING EXERCISES

Example 1 - One day initial course for 24 trainees.

09:00 hrs - 12:30 hrs

- Lectures, "Mine Fires" "Course of Fire" Film "Fire Underground", Discussion.

13:00 hrs

- Split into 3 groups of trainees
 - Gp 1 - Practical - hose drill (wet and dry)
 - Gp 2 - Practical - Oil tray fire
 - Gp 3 - Practical treatment of small fire in gallery

Groups change exercises every 40 minutes.

15:30 hrs

- Discussion

16:00 finish

Example 2 - Gallery set up for normal ventilation (as Circuit 1) fan running. Team deployed from intake slope to search for fire. Heavy smoke in return slope. Team follows intake air, and discovers smoke pouring out of "Gob" into "tail gate". They attempt to enter "gob" and deal with "fire". The "fire" is actually located in main gate "Pack hole". The team eventually deduces this, retreats and re-enters "pack hole" from the main gate "longwall" and tackles the "fire" from the safety of the intake side.

TABLE 6-1

FIRE TRAINING SYLLABUS
AND PROGRAMME

FIRE SUBJECT	NEW MINE EMPLOYEES	O/G WORKMAN	SUPERVISORS	REDUCTION MANAGEMENT	TECHNICAL STAFF (MINING, SAFETY, ENG. VENT.)	SENIOR MANAGEMENT	RESCUE MEN	FIRE FIGHTING TEAMS
Detection of Fire	X	X	X	X	X			X
Basic Fire Theory	X	X					X	X
Portable Extinguishers	X	X	X	X			X	X
Fire Hose (wet & dry drill)	X	X	X	X			X	X
Foam				X	X		X	X
Open Fires	X	X	X	X	X		X	X
Concealed Fires		X	X	X	X		X	X
Spon. Comb.			X	X	X	X	X	X
Smoke - light	X	X	X	X	X		X	X
Smoke - dense			X		X		X	X
Hot and Humid Chamber			X	X	X		X	X
Colliery Emergency Scheme	X	X	X	X	X		X	X
- ditto - advanced			X	X	X		X	X
Specialist lectures				X	X	X	X	X
(N2 ventilation, etc.)				X	X			
Fire incident exercises			X	X	X			
Breathing Apparatus				X		X	X	
Communications - Report	X	X	X	X			X	
- telephone							X	
RAYON OF (RE) TRAINING								
Initial Training	6 hrs	6 hrs	4 hrs	16 hrs	-	-	16 hrs	16 hrs
Fresher Course - Duration	-	1 hr	2 hrs	-	2 hrs	3 hrs	-	3 hrs
Fresher Course - Frequency	-	1 yr	1 yr	-	2 yrs	4 yrs	-	6 wths

APPENDIX A

"INTERPRETING THE STATE OF A MINE FIRE"

by

Donald W. Mitchell and Frank A. Burns

INTERPRETING THE STATE OF A MINE FIRE

by

Donald W. Mitchell¹ and Frank A. Burns²

ABSTRACT

Success in controlling a mine fire depends to a large measure on decision making. Reliable information is essential to answer the critical questions: (1) What is the danger of explosion? (2) Can the firefighters move to safe areas before an explosive atmosphere develops? (3) Are the firefighting techniques effective? (4) Is the fire under control?

Ways to develop this information for decision makers are described. Advice and rules based on experiences at many mine fires are given.

INTRODUCTION

From experience we know that failure to extinguish a fire while it is just developing results in a 50 percent chance that more than eight hours will be required to bring it under control and a 5 percent chance that part or all of the mine will be sealed.

Success in control of fire depends to a large measure on decision making. To achieve that success reliable information is essential to answer the critical questions: (1) Can the firefighters move to safe areas should an explosive concentration develop? (2) How effective are the fire-control methods being used? (3) Is the fire under control?

Analysis of the changing composition of the mine air is the only means presently available to obtain the needed information. This paper describes how best to obtain reliable information and the various ways to interpret the data. This information is based on failures as well as successes at many mine fires in this country and in Europe.

SAMPLING

Taking a sample of mine-fire gases is the first and, oftentimes, the most difficult step in the sampling procedure. It is also one of the most error-prone steps. Too many samples, particularly those taken early in the fire, are not

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reliable. There are two principal reasons for this: (1) few persons trained to take samples are available and as a result, inexperienced persons are pressed into taking samples, and (2) sampling procedures and locations have been dictated by emergency conditions rather than good practice. It is especially important, therefore, that persons making decisions during the early stages of a fire accept analyses and interpretations with caution and with the understanding that they could be wrong.

Sampling Procedures

Decisions should be based on the changing composition of the mine air; never on just one sample. It follows, therefore, that if the choice must be made, it is better to take frequent samples at one point than a few at many points.

Sampling Rule 1.--Samples should be taken at frequent intervals and from precisely the same point(s).

Whether using bottles or hand-held instruments, such as methane detectors and stain tubes, maximize the chance of sampling the fire-produced atmosphere. In most fires the heat and possible toxicity of the air from the fire make it difficult, if not dangerous, to take samples directly. Most samples will be drawn through tubes (pipe).

Sampling Rule 2.--Samples drawn through a tube (pipe) must contain the atmosphere to be sampled. Before taking a sample, draw the to-be-sampled atmosphere through the tube for a period not less than three times longer than required for one exchange (see example 1).

Example 1:

Assume an 80-foot-long 1/4-inch-ID tube. Its volume is 0.027 cubic feet. Assume a hand-operated pump rated at 150 cc/min (0.0053 cfm). The minimum time of pumping prior to taking a sample

is $3 \times \frac{0.027}{0.0053} = 15.3$ minutes. With a water-powered pump rated at

1.5 cfm, the time would be $3 \times \frac{0.027}{1.5} = 3$ + seconds.

Sampling bottles, on occasion, are contaminated prior to use at a mine fire. Contamination is most often caused by the wrong wax being used in the "bullet," although faulty glass sealing, cleaning and evacuation have occurred. Use of the wrong wax causes abnormally high CO and H₂ concentrations; faulty glass sealing may result in the analysis indicating "fresh air"; and, the analysis from an inadequately cleaned or evacuated bottle could be anything except correct.

Sampling Rule 3.--When taking bottle samples, be certain that: (1) the wax in the "bullet" is warm and soft, (2) a good seal is made between the sampling tube and bottle tip before breaking the tip; if the tube is too large in

diameter, use petroleum jelly to help make a good seal, and (3) almost zero time passes between withdrawal of the bottle tip and sealing it with the "bullet."

Sampling Rule 4.--Retake any bottle sample that does not comply with Sampling Rule 3.

Sampling Rule 5.--Use Trickett's Ratio (see section on "Interpreting Samples") to test the reliability of at least one of every five analyses of bottle samples.

Sampling Rule 6.--Retake or reject any sample that infers a large increase or decrease in CO unless the trend is verified from no fewer than two subsequent samples, all of which are tested for reliability by Trickett's Ratio.

Sampling in the Mine

A common error results from taking samples too close to the fire. If samples are taken too close to the fire or if the air around the fire is slow moving, the gases from the fire may be incompletely mixed into the air and thus could show too low as well as too high a concentration of fire products.

Sampling Rule 7.--Take downwind samples at least 10-roadway diameters from the fire (see example 2).

Example 2:

An opening 5-feet high by 18-feet wide has a perimeter (equivalent circumference, C) of 46 feet. Its diameter, d, equals C/π or 14.6-feet. Thus, 10-roadway diameters is 146 feet.

Sampling Rule 8.--Where downwind sampling must be closer than 10-roadway diameters, samples should be taken from three heights, near the center, near the roof, and near the floor, and the results averaged.

Another error results when gases in the air passing over the fire are not considered. That air may be deficient in oxygen (below 20.93 percent) and may be contaminated by oxides of carbon (CO_2 and CO) and methane. In that decisions must be based on the state of the fire, the influence of such air must be considered.

Sampling Rule 9.--Air that is to pass over the fire should be sampled.

Often the least considered yet most critical error is caused when fire-produced gases are diluted before sampling. For example, at one mine fire, CO readings ranged from 2 to 10 ppm for a month. This led to the decision to dewater the flooded fire area. Unfortunately, air from the fire area was less than one percent of the air reaching the sampling point and thus the true concentration of CO was up to 1,200 ppm. The fire rekindled and the mine was reflooded. At another mine fire, the air reaching the sampling point was from both the fire and an adjoining fresh-air intake. Explosibility analysis indicated a "safe" atmosphere--a momentary ventilation disruption allowed the gases immediately outby the fire to roll back and be ignited.

Sampling Rule 10.--Downwind samples should contain the atmosphere from the fire only. Where this is not possible, decisions should be based on the changing trend in the "Index for Carbon Monoxide."

Sampling a Sealed Area

Only water, when it is positively "roofed," prevents interchanges of gas and air between "sealed" and open portions of a mine. A leakage rate as small as 100 cfm will cause the exchange of more than one million cubic feet within a week. Changes in barometric pressure, the paths taken by the air current in the mine, the different atmospheres in and thus densities of the open and sealed areas, and stoppage of a mine fan aids the movement of gases from and of air into sealed areas. Gas-air exchanges will be through roof-bolt holes and through cracks and fissures in the roof, floor and pillars as well as through manmade seals.

Sampling Rule 11.--Samples from sealed areas should be taken only when the barometric pressure is relatively constant or falling. When the pressure across a seal is known, take samples only when the pressure behind the seal is equal to or greater than on the open face of the seal.

The closer the sampling point is to a seal, the more it will be affected by interchanges between the open and sealed areas.

Sampling Rule 12.--Sampling tubes into sealed areas should extend not less than 15 feet and preferably 60 or more feet towards the fire.

Air within a sealed area tends to stratify. Stratification increases with increase in grade. For example, fresh-air leakage flows are strongest near the floor in a dipping entry and near the roof in one that rises.

Sampling Rule 13.--Where sealed areas are on more than a 6 percent grade, samples should be taken at three heights, near the center, near the roof, and near the floor, and the results averaged.

Sampling Through Boreholes

Samples often are taken through boreholes. If the borehole is not cased adequately, samples taken above gas-bearing strata are likely to be contaminated and provide wrong data. Leakage around the borehole collar is difficult, if not impossible, to stop. Samples taken near the collar invariably will be diluted with fresh air even when the borehole is "blowing." When the borehole is "sucking" (the pressure in the mine is below that on the surface), samples taken anywhere within the borehole will be diluted by fresh air. To militate against such problems, sampling tubes should be put through the borehole into the mine. However, tars from the fire tend to condense in and collect on the walls of tubes. The closer the borehole to the fire, the greater the quantity of tars likely to collect in the sampling tubes. The tars will give off CO, CO₂ and H₂; thus, samples taken through tubes downwind of a fire might be contaminated by fire gases evolving from the tars.

Sampling Rule 14.--Sampling points in boreholes preferably should be in the mine. Where this is not practical, then:

- a. Do not sample a "sucking" borehole.
- b. Sampling points should be at least 20-pipe diameters below the collar.
- c. The sample should be marked to show whether the borehole was "blowing," "sucking" or relatively "still." A pressure reading is preferred.
- d. Sample interpretation should be on a methane-free basis unless the methane-make of the borehole is known.

Sampling Rule 15.--Samples taken from long tubes in a borehole should be tested for reliability by Trickett's Ratio.

ANALYZING SAMPLES

A gas chromatograph (GC) is the most accurate means for analyzing samples, PROVIDED:

- a. The GC is calibrated at least daily, preferably using accurate standards having compositions similar to those likely to be analyzed.
- b. The GC is equilibrated.
- c. The GC-operator is experienced.
- d. Caution is taken when using a flame ionization detector for analysis of CO when prior-tested samples contained ethane or the CH₄ content exceeds 10 percent.

One major deficiency of GC is the long time lapse between when a sample is taken and results are obtained. Unless a suitable laboratory is established, reliance is generally placed on hand-held instruments. Hand-held instruments permit rapid collection of data; however, interpretation of the data can be wrong if the inaccuracies of the instruments are not considered. Fortunately, the errors generally indicate that conditions are more hazardous than they really are. Unfortunately, this could lead to premature withdrawal of the firefighters, perhaps allowing a fire to intensify when continuation of direct attack would have been safe and successful.

A methane detector reading of 3 percent might, in reality, be 1 to 5 percent. For example, hydrocarbons, such as ethane and propane, cause higher than correct readings whereas hydrogen, carbon dioxide, carbon monoxide and water vapors cause lower than correct readings. All of those gases are to be expected as byproducts from a fire. Variations will be wider and less safe with interferometer than with hot-wire detectors unless the latter have been inadequately maintained.

Carbon monoxide stain tubes respond to gases such as acetylene, hydrogen sulfide, ethylene and hydrogen. An important increase in length of stain is produced by 1 and 10 ppm of the first two and by 2,500 ppm of the latter two.

Sampling Rule 16.--Use caution when making decisions based on readings from methane detectors and stain tubes. See Sampling Rules 3 to 6 for cautions to be taken when sampling with bottles.

INTERPRETING SAMPLES

The mine fire-produced atmosphere is sampled to provide information that aids in deciding when and whether: (1) an explosive atmosphere is developing; (2) firefighting methods are effective; and, (3) the fire is under control.

Testing Sample Reliability

Assuming samples are taken and analyzed correctly, the first question that needs to be asked is, "Are they reliable?" Experience and Sampling Rules 5 and 15 suggest use of Trickett's Ratio (Tr) to test for reliability. "Tr" is based on the principal that in a fire the molecules of each kind of matter consumed generally will be proportional to the volumes of gas produced. This principal can be expressed by the following simplified but adequate formula:

$$Tr = \frac{CO_2 + 0.75 CO - 0.25 H_2}{0.265 N_2 - O_2}$$

This formula should not be used if the air intake to the fire is oxygen-deficient. This might occur if the intake air is from a poorly ventilated, abandoned area containing abnormally high concentrations of carbon dioxide and methane from another fire or contains injected inert gas. For such conditions:

$$Tr = \frac{(CO_2^a - CO_2^b) + 0.75 (CO^a - CO^b) - 0.25 (H_2^a - H_2^b)}{O_2^b - O_2^a}$$

(a is the concentration of a gas in the downwind and b in the upwind sample.)

Among the advantages of Trickett's Ratio is that fresh-air dilution has no effect on its accuracy. For example, typical samples taken at a recent mine fire through a borehole and at the main fan showed:³

Gas	<u>Borehole</u>		<u>Main Fan</u>	
	Percent	CFM	Percent	CFM
CO ₂	3.33	12	0.27	221
CO	.27	1	.02	16
H ₂	.36	1	.02	16
CH ₄	1.34	5	.21	170
O ₂	15.44	54	20.47	16,785
N ₂	79.26	277	79.01	64,792
Tr		0.62		0.62

³Fire gases had many routes to the fan other than by the borehole given; therefore, the quantities of gas at the fan were far greater than at the borehole.

As will be discussed under the "What Is Burning?" section of this report, mine fire "Tr's" should be in the range 0.4 to 1.6. A "Tr" less than 0.4 generally indicates no fire because sample gases are residual rather than active fire gases or result from oxidation without important heating. One of many examples of this was observed in an eastern Ohio mine where relatively high oxides of carbon raised fear of fire in an abandoned area; thorough search and subsequent events proved, as did the Tr, no fire existed:

CO ₂	0.86%
CO.....	.05%
CH ₄	1.20%
O ₂	15.31%
N ₂	82.58%
Tr.....	0.14

A "Tr" greater than 1.6 should be suspect. Where no possibility exists of wood burning, then a "Tr" greater than 1.0 should be suspect. Further, the more it is greater, the more likely the sample does not represent the atmosphere from a mine fire. For example, a sample taken during what many believed was a controlled stage of a mine fire showed:

CO ₂	0.86%
CO.....	1.26%
H ₂	1.53%
CH ₄	.94%
O ₂	19.81%
N ₂	75.60%
Tr.....	6.81

The abnormal "Tr" subsequently was found to have been caused by contaminated wax in the "bullet" used to seal the bottle. Had these samples not been tested for reliability by Trickett's Ratio, it is possible that the high percentages of Effective Combustible (see fig. 1 and "Explosibility" section of this report for detailed explanation) hydrogen and carbon monoxide, could have led to seriously wrong decisions.

What Is Burning?

Trickett's Ratio can provide insight into what is burning. When the fuel is:

Methane: $Tr = 0.4 - 0.5$

Coal, oil, conveyor belting, insulation, polyurethane foam:
 $Tr = 0.5 - 1.0^4$

Wood: $Tr = 0.9 - 1.6$

Explosibility

Most miners think of methane when concerned about ignition. Indeed, that is the principal gas of concern; however, its flammable limits of 5 to 15 percent are inappropriate when considering safety during a fire.

Hot combustible materials release "fire" gases. The temperatures of the materials and gases will be nearly the same. Assuming that the temperature is $500^{\circ}C$ ($1,100^{\circ}F$), the flammable concentration limits of methane are 3 to 20 percent.

Consider further the effect of "fire" gas concentrations on explosibility limits. Hydrogen and ethane reduce the lower limit; carbon monoxide and hydrogen raise the upper limit; whereas carbon dioxide and excess nitrogen reduce the upper limit.

These interactions could make interpretation of explosibility complex. Over the years, a number of techniques have been devised to simplify and aid interpretation of explosibility. Those that have proven helpful and reasonable when fighting a fire by direct attack are described in the following pages.⁵

Three basic rules to follow when using these techniques are:

Sampling Rule 17.--Interpretation of mine fire conditions should leave a safe margin for error.

Sampling Rule 18.--It is more important to know at an early point in time when an explosive gas concentration is being approached than whether the atmosphere is ignitable.

⁴Testing for HCL and SO_2 and finding neither gives reasonable assurance that neither belting nor insulation are burning. However, HCL is highly soluble in water; if the mine surfaces are wet, the absence of HCL may be meaningless.

⁵Water is the principal extinguishing agent used during direct attack; if temperatures are sufficiently high, a water-gas reaction may occur producing wide ranges in concentrations of H_2 and CO making use of techniques other than those described more difficult and possibly less safe.

Sampling Rule 19.--Dangerous trends can best be observed by plotting fire-gas data against time (see fig. 1).

Before discussing how these diagrams could be used, it is important to understand their deficiencies:

1. Major error can result when the hydrogen and carbon monoxide contents in the fire atmosphere exceed 5 and 3 percent and when samples are diluted (see Sampling Rule 10).
2. Rapid fluctuations in hydrogen and carbon monoxide, which are to be expected when water is used to fight fire, cause rapid shifts in "R" and thus in diagram boundaries.
3. A programmable calculator is essential for timely, on-site computations.
4. The 5 percent Effective Combustible limit is too high where fire gases can contact open flame.
5. A dangerous trend cannot be followed on these diagrams.

Figure 2 shows the explosibility diagram for $R = 0.1$. For coal mine fires being fought by direct attack, this is the only "R" value that need be considered. Seldom in those fires, and never yet during a potentially dangerous trend, has "R" been less than 0.1. Water is the dominant extinguishing agent used in direct attack on a fire; therefore, hydrogen and carbon monoxide are to be expected in the fire gases and "R" will fluctuate among values below 1.0.

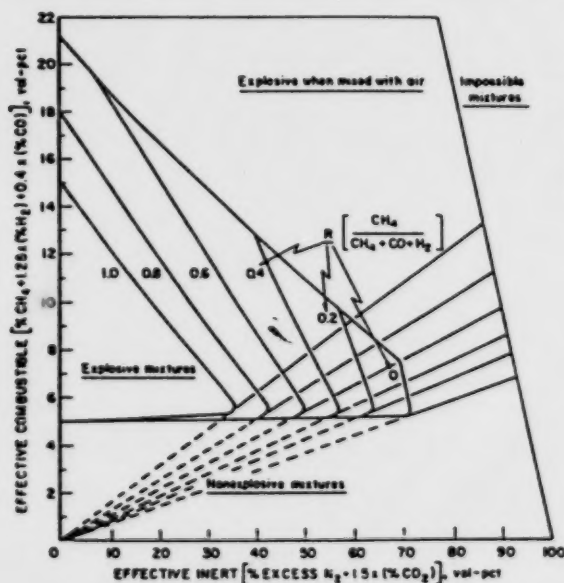


FIGURE 1. - Explosibility diagram.

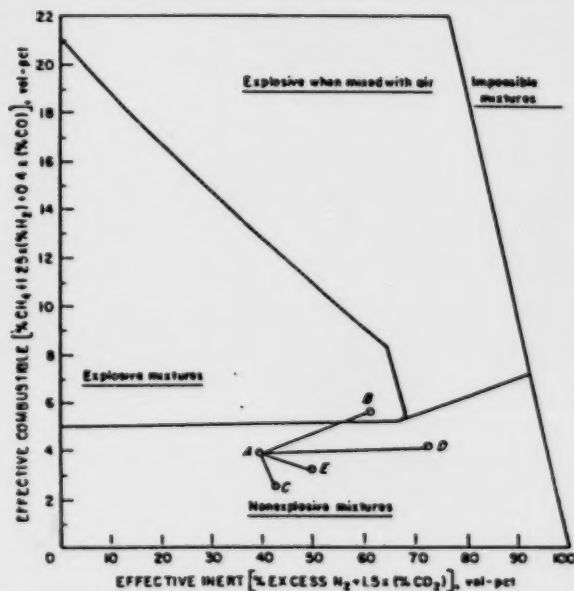


FIGURE 2. - Using the explosibility diagram for $R = 0.1$.

Source: Modified version of figure 1 shown in U.S. Bureau of Mines IC 7901, Determining the Explosibility of Mine Atmospheres by M. G. Zabetakis, R. W. Stahl, and H.A. Watson, 1959, 11 pp.

Use of the actual "R" value, though more accurate, has led to confusion and leaves little margin for safety.

Firefighters who use this diagram gain the advantage of rapid assessment of what might be done to change a trend and then to evaluate the adequacy of their actions. Assume, for example, that Composition Point A represents existing conditions. Reducing the quantity of air flowing over the fire should move Point A towards B which, in this illustration, would be towards a more dangerous condition. When samples indicate an increase in hydrogen, then reducing the quantity of water being applied might cause a trend towards C. The use of high-expansion foam, which should reduce the oxygen though increase hydrogen production, should move Point A towards D. Dry chemicals and inert gases might cause a shift towards E.

None of that, however, answers the critical question "How soon could an explosion occur should existing trends continue?" A means to this answer is obtained by plotting E (Explosibility) against time where:

$$E = E_c \left(\frac{O_2}{MAO} \right)$$

E_c (Effective Combustible) (see fig. 1) = $\%CH_4 + 1.25(\%H_2) + 0.4(\%CO)$

MAO (Maximum Allowable Oxygen) = $5 + 7R = 5 + 7 \left(\frac{CH_4}{CH_4 + H_2 + CO} \right)$

This modification of the Critical Oxygen Content method used by German and Russian mine rescue authorities (13-14) suffers four major deficiencies:

1. Its suitability and accuracy decrease with increase in dilution of samples.
2. The critical boundaries for EXPLOSIVE ($EC = 5$ percent) and POTENTIALLY EXPLOSIVE ($EC = 3.5$ percent) can be selected only from prior experiences during the fire.
3. Those boundaries are different for different sampling points and, for a given sampling point they will shift should conditions in the fire area change radically.
4. The quantities of combustible gases being produced may change abruptly without warning.

With those deficiencies understood, the trend in E (Explosibility of the fire-produced atmosphere) can be used by decision makers as illustrated below and in figure 3. The data in figure 3 are from a recent mine fire while miners were trying to keep the fire from breaking out of the crosscuts into two parallel entries. During the first three hours shown on figure 3, it could be forecasted that unless conditions changed, the atmosphere should be "safe" for at least another 20 hours. By the sixth hour, a deteriorating situation is obvious and it could be forecasted that they had 4 to 5 hours at best to

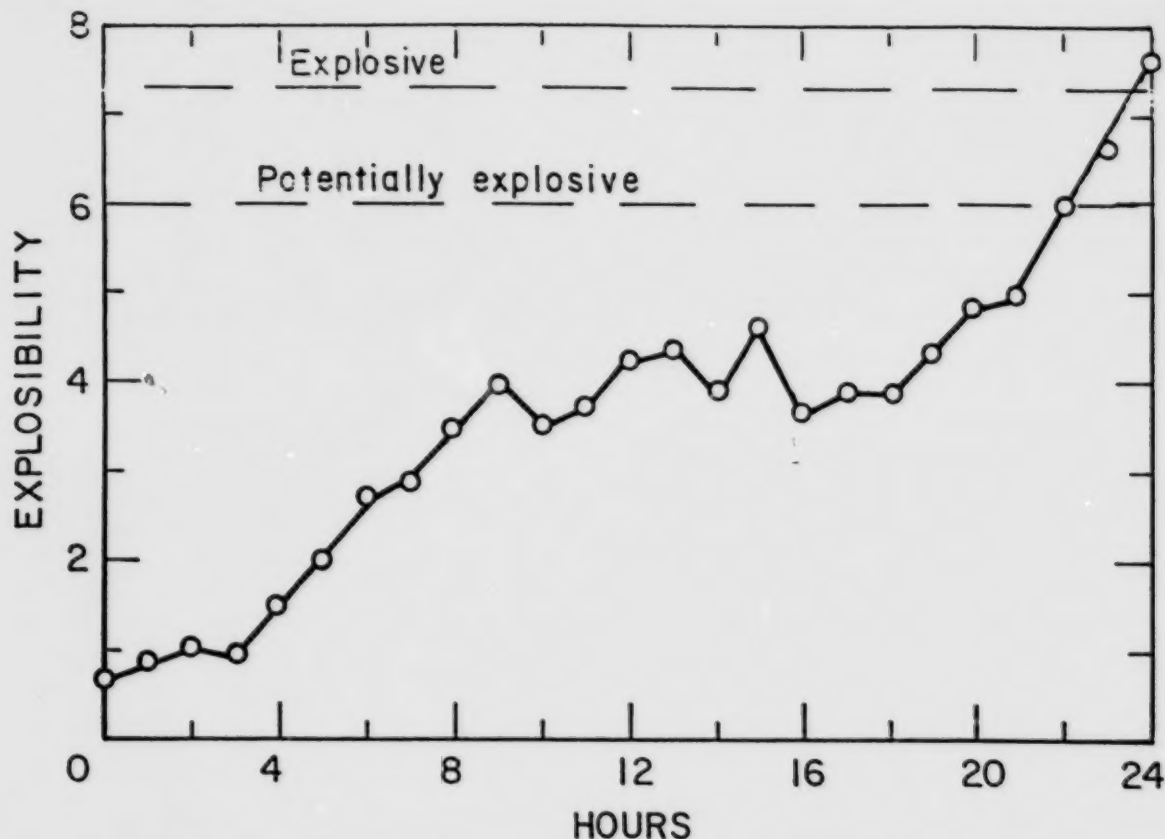


FIGURE 3. - Explosibility of a fire-produced atmosphere.

reverse the trend. Open flames in two crosscuts were extinguished and the trend was slowed. By the 20th hour, worsening conditions were obvious and by the 22nd hour, withdrawal was prudent.

Effectiveness of Firefighting Actions

Once explosive conditions are being monitored and safety is assured, the next critical question to be asked is "Are we bringing this fire under control?" Direct observation provides the best answers; however, when this is impractical, then interpretation of the fire-produced atmosphere must be relied on.

During a recent mine fire it was decided to flood the fire area. However, rapid changes in the Effective Combustible led to the miners, who were building dams in the mine, being withdrawn too frequently for efficient progress. It was decided to inject nitrogen through a borehole in an effort to reduce the oxygen in the air intake and thus, hopefully, to retard the fire. Subsequently, high-expansion foam was injected into boreholes in an effort to

cool the fire. Figure 4 shows how the trend in E (Explosibility of the fire-produced atmosphere) was used to aid decisions.⁶

The key events of this fire were:

- A. Day 2--500 cfm of nitrogen reduced oxygen intake to 19.3 percent; the rising explosibility trend was arrested for two days. During the third day, the worsening conditions could be forecasted and arrangements were made to increase the nitrogen.
- B. Day 4--1,250 cfm of nitrogen reduced the oxygen intake to 17.3 percent and arrested the dangerous trend. By the sixth day it was obvious that either more nitrogen or other means to "quiet" the fire was necessary.
- C. Day 7--1,750 cfm of nitrogen reduced the oxygen intake to 16.2 percent. Plans for injection of high-expansion foam were initiated.
- D. Day 10--Nitrogen stopped; 12 hours later, high-expansion foam was injected through a borehole into a parallel entry.

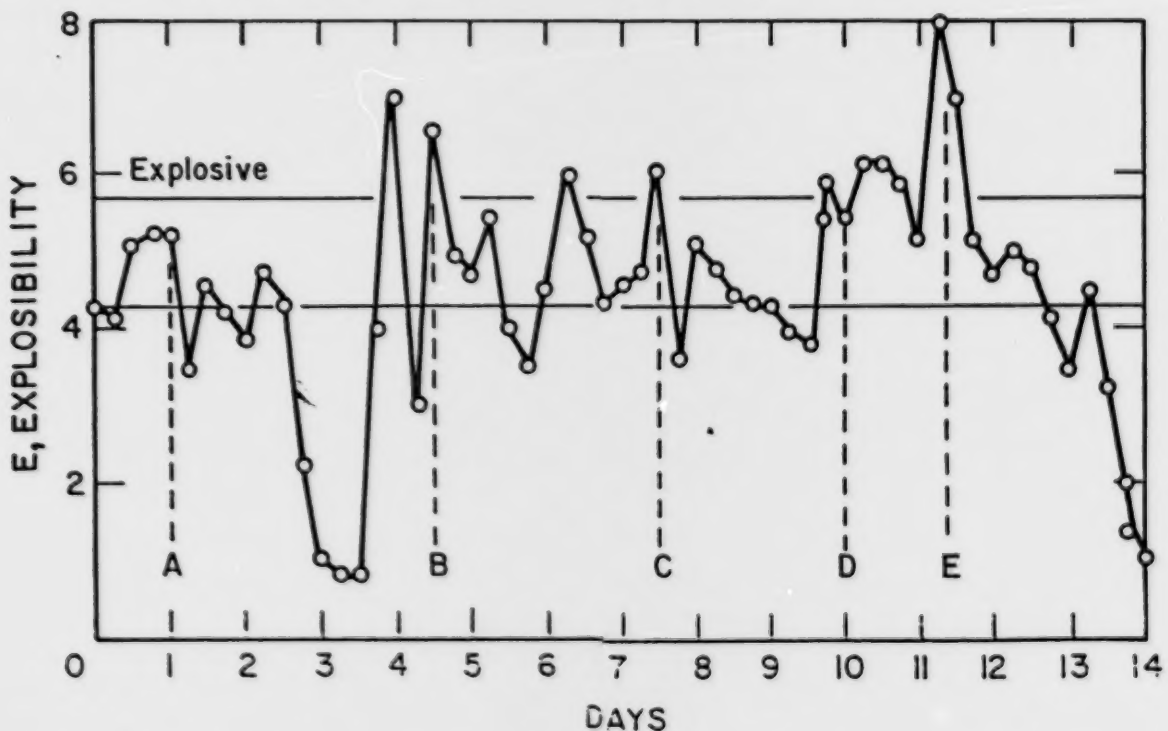


FIGURE 4. - The use of nitrogen and high-expansion foam to reduce the explosibility of a mine fire atmosphere.

⁶Note the different boundaries in figures 3 and 4 for EXPLOSIVE and POTENTIALLY EXPLOSIVE.

- E. Day 11--High expansion foam injected through a borehole inby the sampling point; $\bar{E}$ decreased continuously. Foam injection was stopped two weeks later when flooding began.

The use of $\bar{E}$ to follow trends is effective provided its deficiencies are appreciated. Chief among these is the effect of dilution, the sample containing the atmosphere from two or more unknown air flows. When samples are diluted, reliance should be placed on the "Index for Carbon Monoxide" (I_{CO}).⁷ This Index is unaffected by dilution;⁸ it is temperature dependent and thus rises with increase in temperature of the material producing carbon monoxide (1, 14, 16, 21-23, 27).

Index for Carbon Monoxide

To calculate I_{CO} :

1. When the air intake has the natural oxygen-to-nitrogen ratio of 0.265:

$$I_{CO} = \frac{CO}{0.265 N_2 - O_2}$$

2. When this is not the condition, such as when inert gas is being used:

$$I_{CO} = \frac{CO}{\left(\frac{O_2'}{N_2'}\right) \left(N_2\right) - O_2}$$

(O_2' and N_2' are from the intake samples; O_2 and N_2 are from the return air samples.)

Figure 5 shows I_{CO} for the same samples used in figure 4. The story told by this trend, though somewhat different, is supportive and informative.

- A. 500 cfm of nitrogen had no cooling effect.
- B. and C. 1,250 and 1,750 cfm of nitrogen reduced the temperature of the fire; less of the methane being liberated was being ignited causing $\bar{E}$ to increase (fig. 4 and a plot, not shown, for methane versus time).
- D. Stopping the nitrogen flow did not affect temperatures.
- E. The cooling effect of high-expansion foam was not obvious until after Day 14, $I_{CO} = 5$ when flooding began.

⁷The ratios for carbon dioxide and hydrogen to oxygen consumed have also been used. These are less practicable than I_{CO} . Carbon dioxide may appear from sources other than the fire-produced atmosphere. Hydrogen is produced at considerably higher temperatures than is carbon monoxide and thus is not available during the initial and final stages of a fire.

⁸Error in I_{CO} calculations increases with decrease in CO and with increase in O_2 . Too much dilution could result in I_{CO} having higher than actual value. These errors normally indicated dangerous conditions exist when actually they do not.

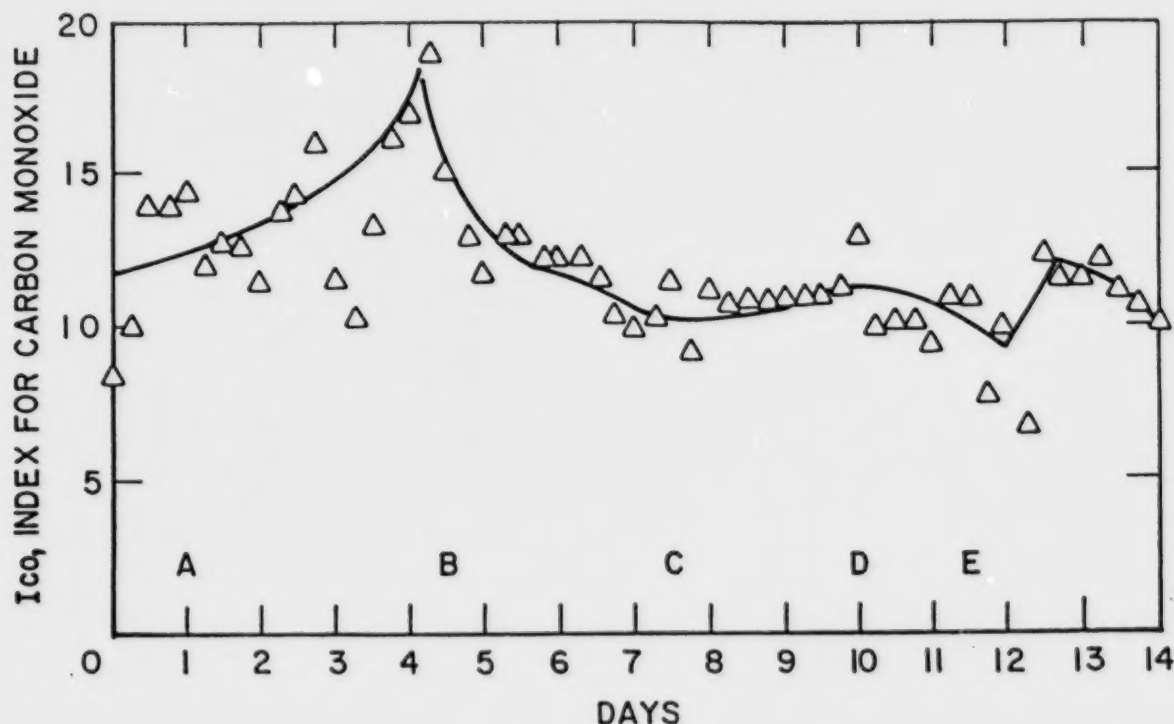


FIGURE 5. - Index for carbon monoxide when nitrogen and high-expansion foam are used to control a mine fire.

Individual Gases

Analysis of the relationships among individual gases aids study of conditions within a sealed area. However, it is generally neither as convenient nor more informative than plots of E (Explosibility) and Ico (Index for Carbon Monoxide). Nor is it suitable for study of conditions during direct attack of a fire or when a fire is flooded, but water is not roofed.⁹

Size of a Fire

It is of interest, but not a necessity, to know about changes in the quantity of fuel burning. For example, the quantities burning during selected stages of a recent mine fire are given in Table 1.

⁹Changing temperatures, quantities and types of material burning cause fluctuations, often major, in the pressure differential across the fire area. Falls of roof and ribs cause changes in the ventilating airflow paths. Thus, the quantities of products of combustion reaching a sampling point may or may not represent actual conditions; they are less representative for samples taken near rather than far from the fire; and for a distant sampling point, their meaningfulness depends on whether all of the fire atmosphere flow is to that point.

TABLE 1. - Estimated quantity of fuel burning
in a selected sample mine fire

<u>Date</u>	<u>Fuel,</u> <u>lb/min</u>	<u>Remarks</u>
2/11	85	Flaming wood crossbars observed.
2/12	70	Direct attack; firefighting continued.
2/14	90	Smoke "too heavy" for apparatus team.
4/5-12	15	Fire area "flooded."
6/3	6	Plans initiated to lower the water.
6/24	65	Heat and dense smoke in fire area.
10/22	0	Plans initiated to lower the water.
12/13	3	Fire area dewatered.
12/17	30	Miners working towards fire area.
12/23	50	High-expansion foam injected into borehole.
1/6	55	Miners working towards fire.
1/23	60	Miners applying water onto caved material.

"F" can be estimated as shown in the following examples:

A. Q, Quantity of airflow across the fire = 22,000 cfm.

O_2' , oxygen content of intake air to fire = 20.94%.

O_2 , oxygen content in return air from fire = 11.72%.

Tr, Trickett's ratio (see "Testing Sample Reliability" section of this report) = 0.72, therefore coal is the principal combustible.

B. ΔO_2 , oxygen consumed by fire = $Q(O_2' - O_2)$
= 22,000 (0.2094 - 0.1172) = 2,028 cfm.

C. "F" = $(\Delta O_2)(k)$

k coal = 0.03

k wood = 0.08

"F" = (2,028)(0.03) = 60 pounds of coal burning per minute.

Is the Fire Out?

In sealed areas, flames normally disappear when the oxygen concentration is maintained below 12 percent. However, heated coals, wood and rock will remain incandescent or smolder indefinitely when the oxygen content is as low as 1 percent (2-3, 23).

Flooding should cool a fire as well as aid in maintaining near 0 percent oxygen. Unfortunately, conditions within a flooded area cannot be determined with certainty. Water may not be in contact with all of the roof. It may not

penetrate into tightly caved rock. In fact, in a recent mine fire, flooding on two occasions failed to cool large areas of roof, though the water level was believed to be well above most of the roof, and failed to quench pieces of wood and coal buried within falls of roof. Hot strata and hot to incandescent materials are the nucleus for reinitiating mine fires.

In decisions to reopen a sealed area or to lower the flood level, all facts and consequences must be weighed. The fact that a fire has subsided towards extinction can be demonstrated by following the trend in the Index for Carbon Monoxide. Neither that technique nor any other known technique can provide a guarantee that the fire is out and, if out, will not reignite. Should trends be used to aid in deciding when to reopen a fire area, it is essential that the trend be followed over a sufficiently long period to give confidence that the approach to extinction is real and sustained.

The question "Is the fire out?" can only be answered after ventilation is reestablished and the fire does not rekindle. A more practical question is, "If it does rekindle, can all of the heated materials be cooled or removed before the fire becomes active?"

CONCLUSIONS

Computations and diagrams are positive aids to persons responsible for extinguishing a mine fire. They permit forecasting trends and evaluating the effectiveness of firefighting activities. Abrupt changes, however, occur without warning. Diagrams and computations must never be allowed to displace caution and good sense.

REFERENCES

1. Chamberlain, E. A., et al. The Ambient Temperature Oxidation of Coal in Relation to the Early Detection of Spontaneous Heatings. The Mining Engineer, v. 30, 1970-1971, No. 121, pp. 1-15.
2. Coward, H. F. Explosibility of Atmospheres Behind Stoppings. Trans. Inst. Mining Engineers, 1928-1929, 77, 94 pp.
3. Dalverny, R. W., et al. Continuous Gas Sampling Using Tube Bundles at the Joanne Mine Fire. BuMines TPR 92, June 1975, 12 pp.
4. Dalzell, R. W., et al. Early Fire Warning Systems. Mining Congress Journal, 62, 1976, No. 3, pp. 22-27.
5. Daugherty, J. J. Control of Mine Fires. West Virginia U. Press, Morgantown, West Virginia, 1969, 89 pp.
6. Flachowski, G., and W. Voelkel. Methods and Instruments for the Early Detection of Mine Fires. Bergakademie 20, 1968, No. 10, pp. 577-582.
7. Forbes, J. J., and G. W. Grove. Procedure in Sealing and Unsealing Mine Fires and Recovery Operations Following Mine Explosions. BuMines Miner's Circular 36, 1948, 84 pp.
8. Ghosh, A. K., and B. D. Banerjee. The Use of the Carbon-Hydrogen Ratio of the Fuel Burnt as an Index in the Investigation of Explosives and Underground in Coal Mines. 12th International Conference, Mine Safety Res. Establishments, Dortmund, 1967, 19 pp.
9. Hartstein, A. M., and D. R. Forshey. Coal Mine Combustion Products: Identification and Analysis. BuMines RI 7872, 1974, 12 pp.
10. Howarth, H. C., et al. Experiments on the Control of Coal-Mine Fires. Mine Inspectors Inst. of America, 1949, 9 pp.
11. Hughes, A. J., and W. E. Raybould. The Explosibility of Mine Fire Gases. Colliery Guardian, March 24, 1960, pp. 333-338.
12. Jones, J. E., and J. C. Trickett. Some Observations on the Examination of Gases Resulting From Explosions in Collieries. Trans. Inst. Mining Engineers, 114, 1954-1955, pp. 768-790.
13. Koch, F. J. Methods of Determining the Explosibility of Mine Gas. International Seminar for Mining Engineers, Saarbruecken, Oct. 12-14, 1971
14. Mine Rescue Center Essen, Guidelines for the Evaluation of Gas Samples When Fighting Mine Fires, Gluckauf/Essen, 1954.

15. Mitchell, D. W. Problems in Fire Control in Coal Mines. Proceedings Conference on Underground Mining Environment, U. of Mo-Rolla, Oct. 27-29, 1971, pp. 251-258.
16. _____. The CO Index, What It Should Mean to You. National Safety Council Newsletter, Dec. 1972, 3 pp.
17. Mitchell, D. W., et al. Flame Propagation on Conveyor Belts. BuMines RI 7053, 1967, 14 pp.
18. Mitchell, D. Practical Aspects of Controlling an Underground Fire on a Mining Machine. BuMines RI 5846, 1961, 20 pp.
19. _____. Fighting Mine Fires. Trans. Soc. of Mining Engineers, June 1962, pp. 218-224.
20. Mitchell, D. W., et al. Controlling Mine Fires with High Expansion Foam. BuMines RI 5632, July 1960, 28 pp.
21. Mueller, R. Significance and Scope of Graham's Ratio in Practical Applications. International Seminar for Mining Engineers, Saarbruecken, Oct. 12-14, 1971.
22. Van Der Walt, N. T., et al. A Fire Detection System for Miners. International Mine Ventilation Congress, Johannesburg, 1975.
23. Willet, H. L. The Interpretation of Samples From Behind Stoppings With a View to Reopening. Transact Inst. Mining Engineers, Ill, 1951-1952, pp. 629-650.
24. Willet, H. L., et al. Sealing Off Fires Underground. The Mining Engineer, 1962, pp. 709-760.
25. Zabetakis, M. G. Evaluation of Mine Air Samples Following Fire in No. 3 Mine, Wolf Creek Collieries, Lovely, Martin County, Kentucky. BuMines H&SRTC Report, 68-7-S.1, Aug. 18, 1967, 9 pp.
26. Zabetakis, M. G., et al. Determining the Explosibility of Mine Atmospheres. BuMines IC 7901, 1959, 11 pp.
27. Zeidler, U. CO Monitoring and Alarm Installations in German Coal Mines. Gluckauf, 1972, pp. 797-805.

APPENDIX B

CONTENTS

- . USBM Pittsburgh Research Centre
- . CHERCHAR - France, Experimental Fire Gallery,
Verneuil-en-Hallette
- . Hauptstelle Mine Rescue Centre, Essen, Germany
- . Central Mining Institute, Poland;
- list of papers and research work produced
by the Ventilation Department.
- . Londonderry Industrial Safety Centre,
N.W.W. Australia,
"Design of a full scale Fire Gallery"
- . Publications concerning Fires and Explosions
1980 - 1987

UNITED STATES
BUREAU OF MINES
PITTSBURGH RESEARCH CENTRE

THE PITTSBURGH RESEARCH CENTER: HISTORY AND SCOPE

In 1910, the newly created Bureau of Mines (Act of Congress 36, Stat. 369, March 16, 1910) acquired a 38-acre tract of land at Bruceton, Pa. This property included a small coal mine, later to be known as the Experimental Mine. The objective was to use this mine for the large-scale underground research needed to support one of the Bureau's main initial functions—to provide the mining industry with safer coal mine explosives. In 1920, when the Bureau headquarters moved from the Government Arsenal in Pittsburgh to the Central Experiment Station at 4800 Forbes Avenue, Pittsburgh, Pa., the explosives research and testing activities were transferred to Bruceton. Subsequent land acquisitions increased the area of the Bruceton Explosives Testing Station to close to 250 acres. However, for many years the Center's activities remained headquartered at Forbes Avenue.

Passage of the 1969 Federal Coal Mine Health and Safety Act brought a major broadening of the Center's mission. To the longstanding programs on explosives and fires and explosions, research was added or expanded to control respirable dusts and other atmospheric pollutants encountered in underground mines, reduce noise exposure of miners, decrease methane emissions, protect against roof and rock falls, improve mine ventilation, eliminate a wide range of industrial safety hazards, and develop new technology for postdisaster survival and rescue. Conservation and reclamation of mined lands became another major activity, aimed at such environmental problems as acid mine drainage, fires in abandoned mines and waste dumps, and ground subsidence. New mining technologies were investigated to meet the needs of an industry producing under increasingly difficult conditions, while remaining compatible with health, safety, and the environment. This expansion in program goals was reflected in a series of administrative mergers which, beginning in 1969, led to the formation in August, 1979, of the present Pittsburgh Research Center.

With these rapid programmatic changes came the centralization of all activities at Bruceton, where space was available for new installations. Today, the Pittsburgh Research Center is headquartered at Bruceton, Pa. The Experimental Mine has been expanded considerably and the Safety Research Coal Mine has been added. A third underground facility, the Lake Lynn Laboratory, located some fifty miles south of Pittsburgh, became operational in 1982. Its remote location makes it suitable for large-scale fire and explosion research, research on new explosives, and other mine-scale R&D no longer possible in the increasingly residential Bruceton area.

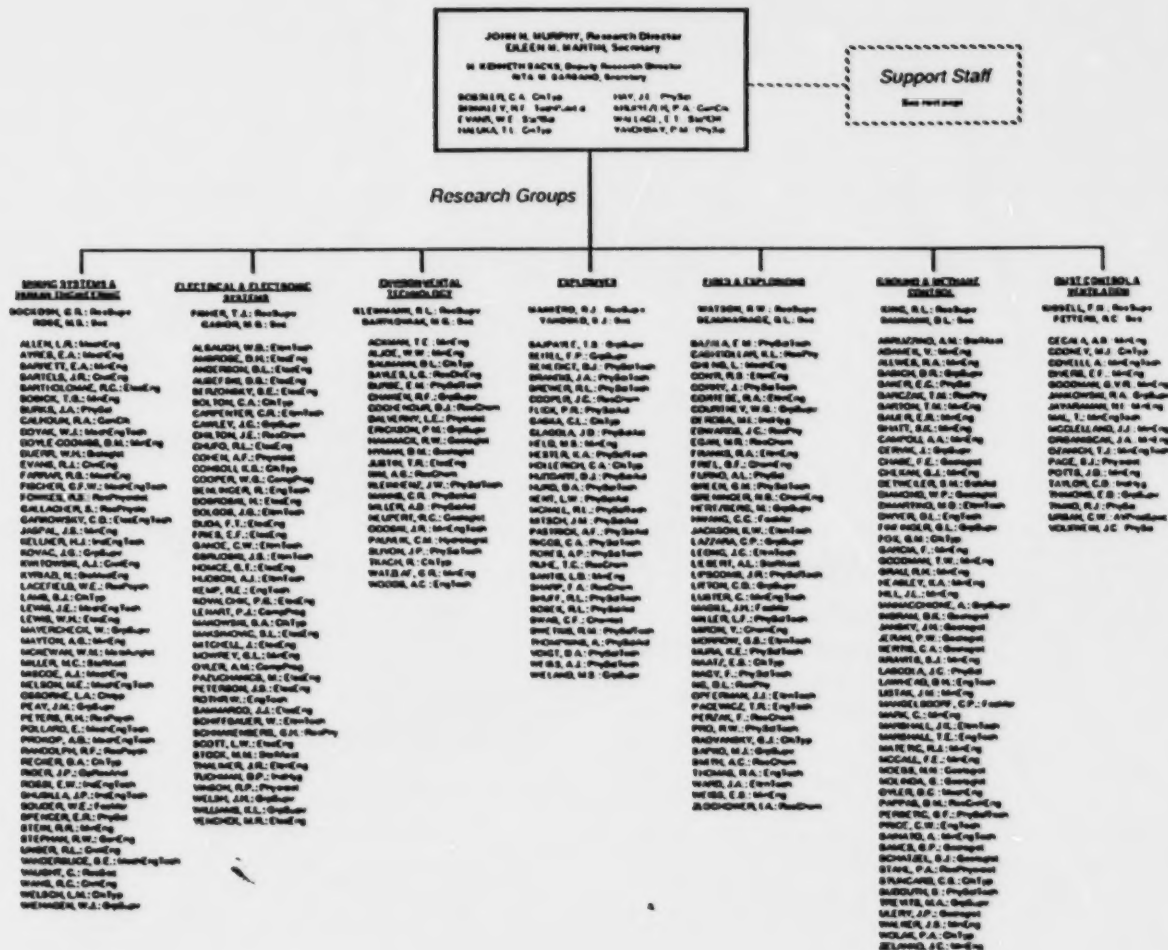
Effective September, 1982, the Department of Energy (DOE) Coal Productivity activities were assigned to the Bureau, including the Bruceton Mining Equipment Test Facility (METF), a 9-acre installation which is unique in the U.S. Major features of the METF are a mine roof simulator capable of 3,000,000 lbs of force for load tests of roof support systems, an impact tester for studies of dynamic roof support devices, full-scale facilities for research on coal cutting and haulage. Another major laboratory, the Wire Rope Laboratory, began operation in FY 1984.

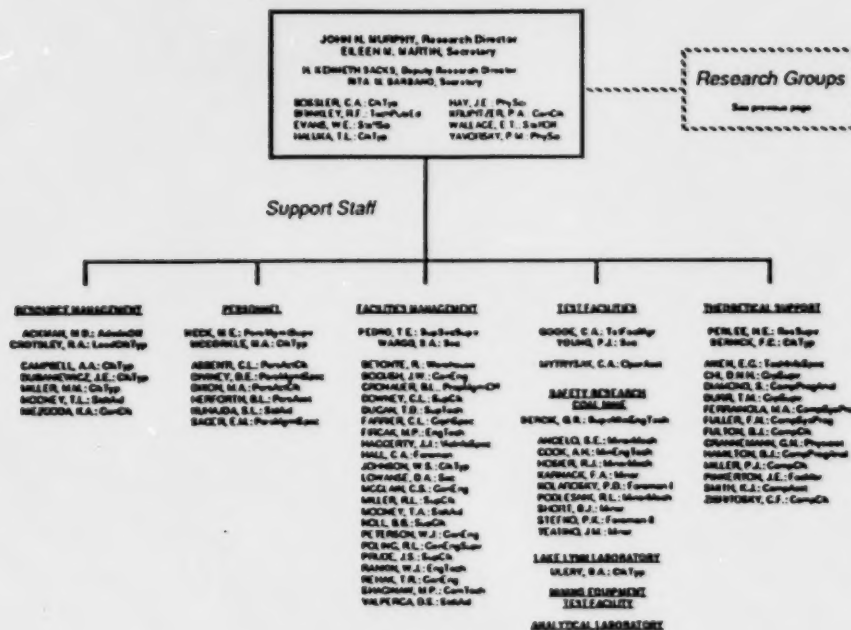
Fire and Explosion Testing Capabilities

- Two underground experimental mines for conducting full-scale fire detection, propagation and Extinguishment studies
- Surface fire gallery for large-scale flammability tests of mine materials, such as conveyor belting
- In-mine test facility for evaluating the fire endurance of mine stoppings.
- Laboratory-scale conveyor belt fire tunnel for evaluating the fire resistance of belting
- Small-scale standard flammability test apparatus for fire resistance testing of brattice cloth and rigid ventilation ducting
- Hot surface test apparatus for determining the ignition temperature of dust layers
- Laboratory-scale adiabatic heating apparatus for evaluating the self-heating tendencies of coals and investigating the spontaneous combustion process.
- Large-scale spontaneous combustion facility for investigating the self-heating of a 15-ton coalbed.
- Test apparatus for measuring the minimum oxygen concentration to support candle-like combustion of materials (limiting oxygen index) ASTM D 2863
- Test apparatus for determining flash point of liquids
- Scanning electron microscope with multichannel x-ray analyzer for studying fire and explosion residues
- Various size ventilated tunnels to evaluate fire detection sensors, including CO and smoke
- 250 watt CO₂ laser system for subjecting materials to high heat flux
- Computer systems for developing sophisticated mathematical fire models, such as for the self-heating of a pile of coal and the growth and propagation of mine fires

Fire and Explosion Testing Capabilities (Cont'd)

- Operating computer programs to determine spread of mine fire contaminants and to calculate fundamental properties such as adiabatic flame temperatures.

PITTSBURGH RESEARCH CENTER

PITTSBURGH RESEARCH CENTER

**PITTSBURGH RESEARCH CENTER
FISCAL YEAR 1988 FUNDING**

Program	In-House Funding \$K	Active Contracts No.
Health, Safety, and Mining Technology	\$20,115	38
Environmental Technology	\$1,211	11
TOTAL	\$21,366	49

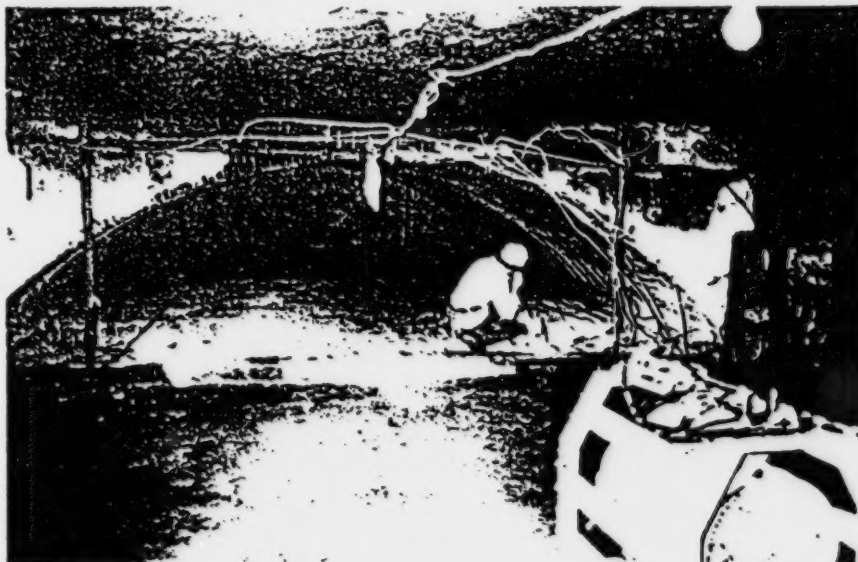
Personnel	Full-time	Other
Professional	186	17
Technical	93	7
Clerical	41	18
TOTAL	320	42

EXPERIMENTAL FACILITIES

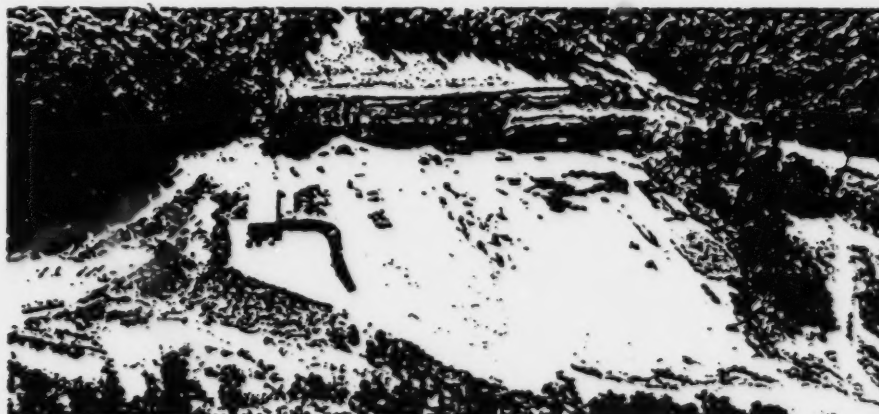
Operation of the PRC Underground Research Facilities

The Safety Research Coal Mine and the Experimental Mine are multipurpose full-scale research facilities. Although cut together, they are separated by explosion-proof bulkheads. The Safety Research Coal Mine is subject to Federal mine health and safety regulations; it is used to evaluate new technology under actual mine conditions before transferring it into the field. The Experimental Mine is exempted from certain regulations to permit its use for large-scale experiments involving mine fires and explosions. The Lake Lynn Laboratory is also a multipurpose test facility, sufficiently remote from residential areas, to be used for large-scale experiments involving explosives, and gas and dust explosions. It offers the modern mine widths made possible by advanced roof support technol-

Preparing for a fire test in the Experimental Mine at Bruceton, PA.



ogy. Moveable explosion-proof bulkheads allow single entry and triple entry longwall faces to be realized. All three mines operate in support of Bureau research and are available to other government agencies and Bureau contractors for relevant research.



The Bureau's Lake Lynn Laboratory offers ample space for large-scale underground and surface research on mine fires, explosions, and explosives

Information Circular 8911

Lake Lynn Laboratory: Construction, Physical Description, and Capability

By Robert H. Mattes, Alex Bacho, and Lewis V. Wade



UNITED STATES DEPARTMENT OF THE INTERIOR

James G. Watt, Secretary

BUREAU OF MINES

Robert C. Horton, Director

INTRODUCTION

A HISTORY OF BUREAU OF MINES INVOLVEMENTS
IN FIRES AND EXPLOSIONS RESEARCH

In 1910, the newly created Bureau of Mines (Act of Congress 36 Stat. 369, March 16, 1910) acquired a 36-acre tract of land at Bruceton, Pa., where an Experimental Mine was opened for use in large-scale research needed to support what was then the Bureau's main function--prevention and suppression of gas and coal dust explosions and the schedule testing and approval of coal mine explosives. The Bureau's schedule testing was initially carried out at the Government Arsenal in Pittsburgh, but when the Bureau's headquarters moved from the Arsenal to the Central Experiment Station at 4800 Forbes Avenue, for reasons of safety the explosives research and testing activities were transferred to the new Explosives Experimental Station at Bruceton. Later the Bruceton facility became the Explosives Testing Station; it is presently known as the Pittsburgh Research Center.

From 1880 to the present, about 500 major gas and dust explosions and several thousand minor explosions and ignitions have occurred in U.S. coal mines. The number of fatalities from these occurrences exceeds 15,000. Since 1910, the Bureau of Mines has been involved in research to combat coal mine gas and dust explosions. The Bureau has conducted over 3,900 large-scale coal dust and gas explosions in the Bruceton Experimental Mine of the Pittsburgh Research Center (PRC) complex. In 1961 the Bureau had to curtail large-scale coal dust explosion experiments because homes were being erected less than a mile from the Bruceton station. The Experimental Mine entries (6 ft high by 9 ft wide), while representative of mine geometries of the 1920's and 1930's, were no longer representative of the greater span mine geometries made possible by modern roof-support techniques. Furthermore, with the recurring application of longwall mining, a need existed to conduct explosion-related research in geometries

similar to that of longwall panels; this could not be accomplished in the Experimental Mine.

In 1968 following the Farmington Mine explosion, the need to test barriers (devices to suppress coal dust explosion) under strong-explosion conditions became evident. The need for a test facility to conduct large-scale fire tests became even more imperative following the Sunshine Mine disaster in 1972.

Considering the continuing need for research to combat mine fires and coal mine gas and dust explosions, a companion facility to the Bruceton Experimental Mine was pursued. In the late 1970's, the Lake Lynn limestone mine was found to meet the experimental research needs for safeguarding miners against the risk of fires and gas and dust explosions. Planning and design of the Lake Lynn Laboratory was initiated, and construction work began on December 12, 1979. The underground development at Lake Lynn was designed to yield coal-mine-sized entries and configurations. A benefit of having such developments in limestone is the relative absence of shales that cause continuing roof control problems as they weather. A list of the major contractors and suppliers that participated in the design and construction of the Lake Lynn Laboratory and a chronology of activities are presented in the appendix, along with a description of the Bruceton Experimental Mine.

PURPOSE OF LAKE LYNN LABORATORY

The Lake Lynn Laboratory was chosen to alleviate the major constraints in carrying out explosion research at the Bruceton Experimental Mines. The Lake Lynn Laboratory provides the Bureau with a dedicated and remote location sufficiently removed from residences to allow for the testing of large-scale detonations with explosives and deflagrations of coal and gas explosions. In addition, Lake Lynn simulates modern mine widths based on advanced roof support

technology. The availability of the Lake Lynn facility, in conjunction with continued work at the Bruceton Experimental Mine, will permit enhanced and accelerated research on fires and explosions.

The underground layout of Lake Lynn allows full-scale research of explosion propagation and suppression as encountered in modern U.S. coal mining. (More detail on the Lake Lynn layout is contained later in this report.)

Some specific areas of utilization of the Lake Lynn Laboratory include--

- evaluating fire and explosion extinguishing devices.
- testing passive and active explosion barriers for the range of weak to strong explosions (gas, coal dust, oil shale, and other dust and oil vapors).
- evaluating ventilation stopping and bulkheads.
- providing an underground test area for prototype mining equipment prior to testing in operating mines.
- providing a network of passages for ventilation studies, including large (50-by 30-ft) workings.
- conducting roof support studies.
- conducting large-scale blasting studies using 4- to 8-in-diam explosive charges (for oil shale acceptability needs).
- monitoring effects of ground vibrations.
- determining toxic hazards of explosives and diesel engines.
- determining explosion limits for coal and oil shale dust.
- performing explosive tests on the highwall bench (surface mining).

- investigating methane layering in large workings (salt, shale, gassy non-coal).

- investigating explosion hazards of mists and vapors (oil, shale, tar sands).

- evaluating remote methane detection hardware.

- evaluating effectiveness and incendiarity of large-scale explosive charges.

- investigating novel blasting concepts (active stemming, face inerting).

- studying vibrations from explosives and blasts.

- providing a remote site for explosives destruction.

- conducting equipment maneuverability and functional tests.

OVERVIEW OF THE GEOMETRIES OF THE FACILITY

The facility occupies approximately 80 acres and is located 15 miles north of Morgantown, W. Va. (14 miles south of Uniontown, Pa.). Figure 1 shows the location of the facility. The site for the laboratory was provided by the Martin-Marietta Corp.

The underground facility consists of approximately 25,000 ft of 50-ft-wide by 30-ft-high entries that were developed in the mid-1960's as part of a commercial limestone mining operation and 7,500 ft of 18-ft-wide by 6.5-ft-high entries developed in 1980-81. The new entries' actual dimensions range from 6.2 to 7.5 ft high by 17.5 to 22 ft wide. Figure 2 shows a plan view of underground entries with the "new" and "old" developments identified. Figure 3 shows the approximate dimensions of the facility, and figure 4 shows the control-support building.

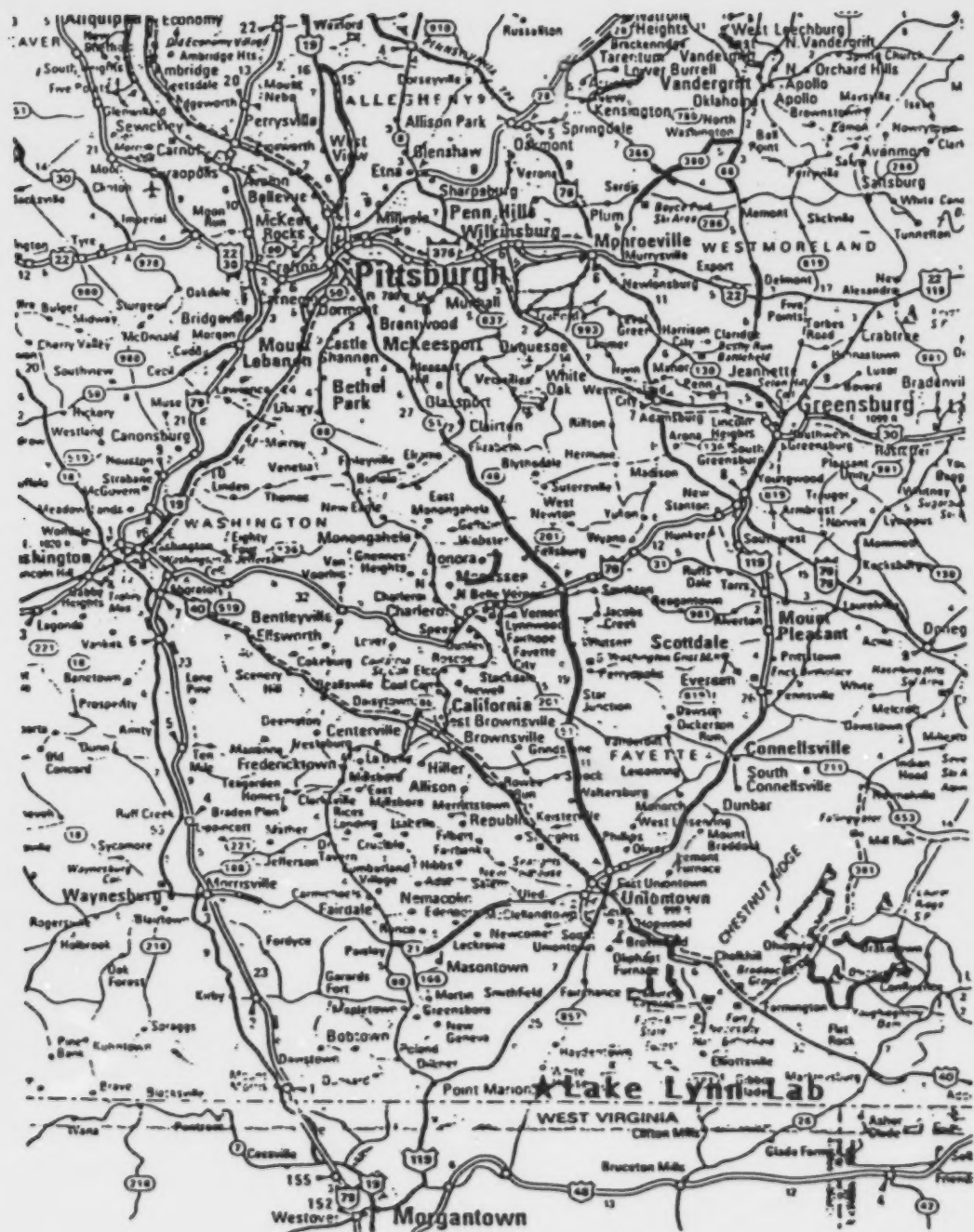


FIGURE 1. - Location of the Lake Lynn Laboratory.

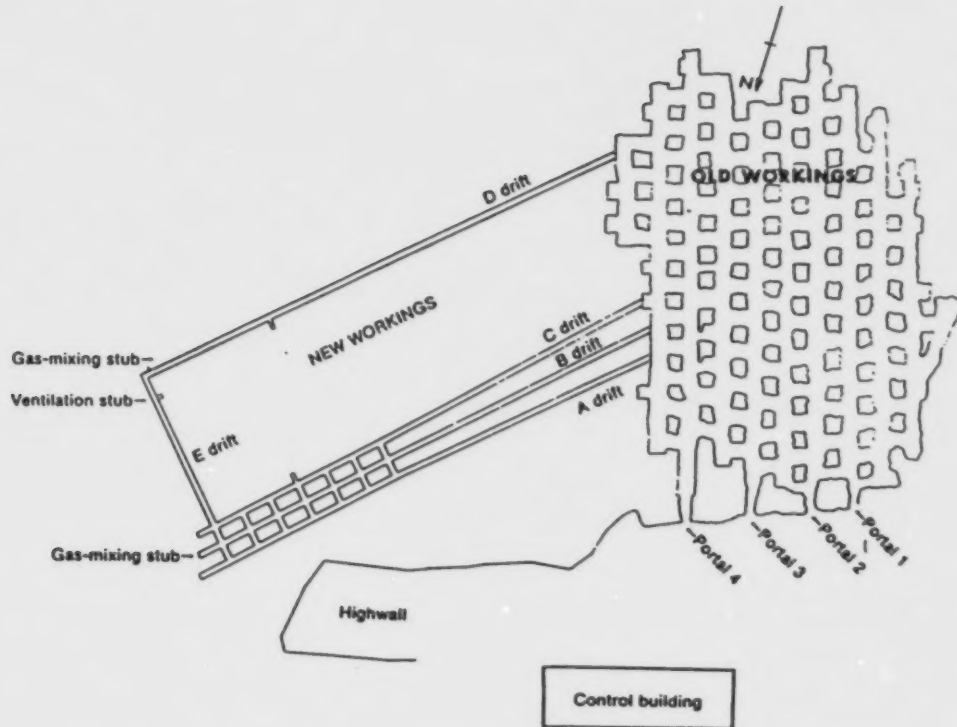


FIGURE 2. - Plan view of underground workings.

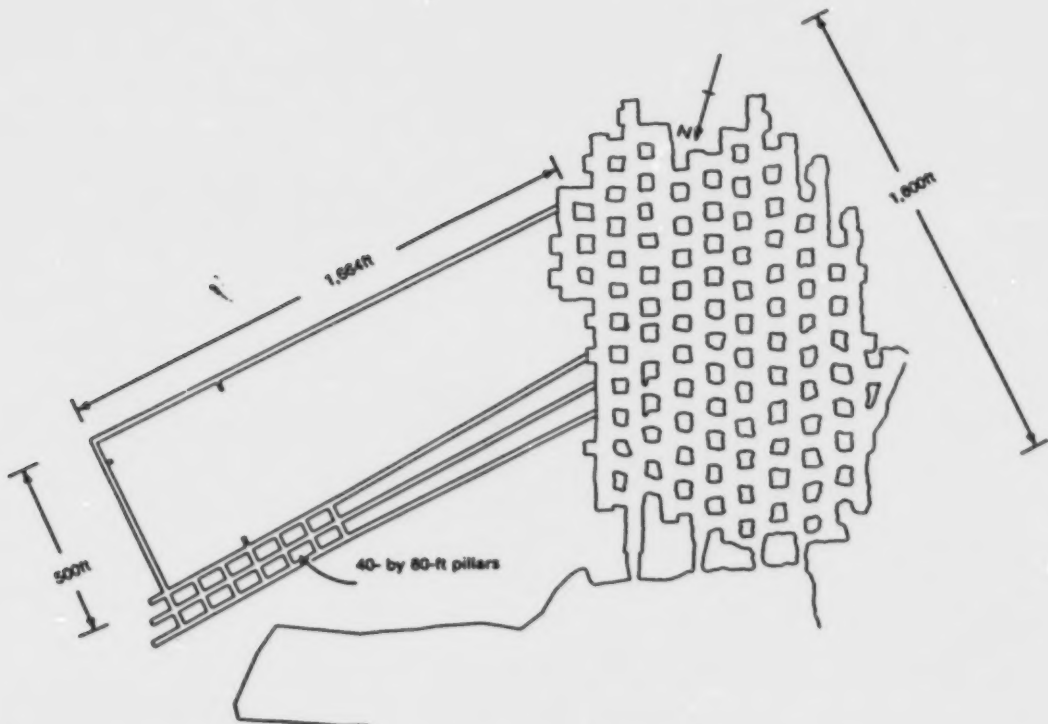


FIGURE 3. - Approximate dimensions of the underground workings.



FIGURE 4. - Control building.

The underground workings are accessed by four portals located in the highwall approximately 200 ft apart. Portal 4 is shown in figure 6. The portal openings are 21 ft wide by 24 ft high and are identified in figure 2.

The surface facility consists of--

- the area above the underground workings, including the gas analysis building, compressor building, and fan house.

- nearly 4 acres of level quarry floor located at the base of a 1,500-running-foot highwall. The highwall

ranges in height from 130 to 40 ft (shown in figs. 7 and 8).

- a 7,200 ft², Control-Support Building (fig. 4).

The underground workings are located in the Greenbrier Limestone Formation.

The cover over the new workings ranges from 180 to 310 ft, while the cover at the ventilation shaft is 284 ft.

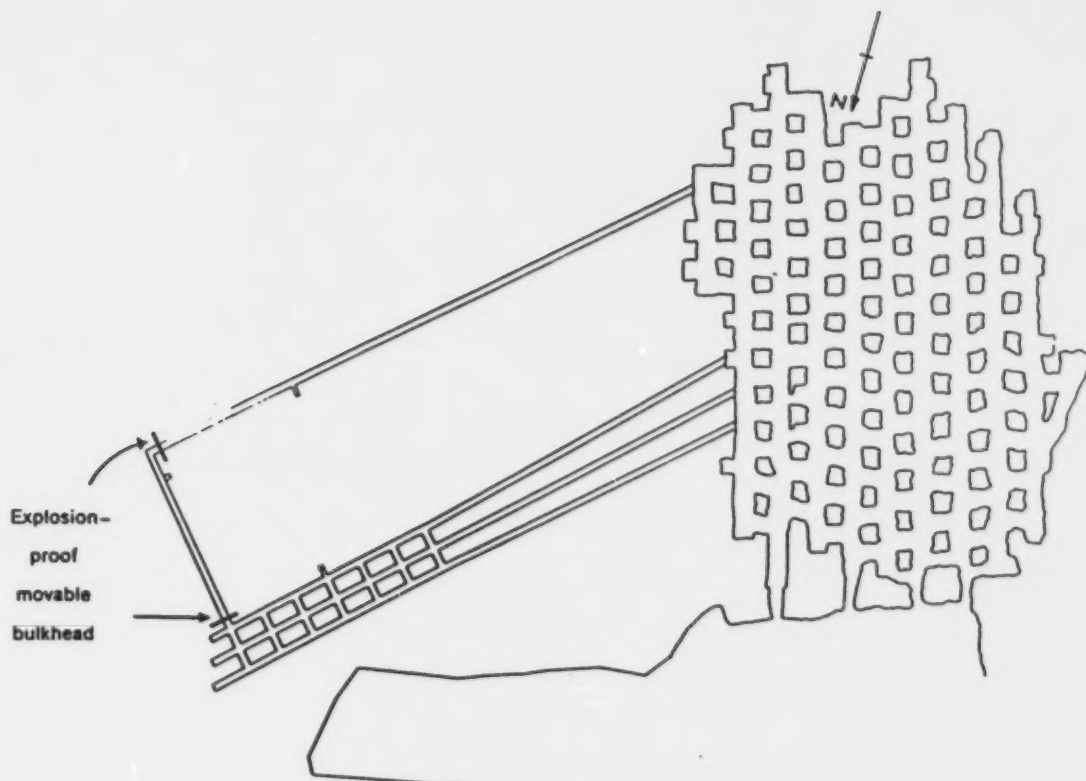


FIGURE 10. - Explosionproof bulkhead location.

Each bulkhead is equipped with a 24-in butterfly valve (fig. 15) that can be remotely operated from the control building. These valves allow for partial airflow through a closed bulkhead. This partial airflow displaces explosion products from a test zone following an explosion and prior to workers' reentering the mine.

The circumference of each face of each bulkhead is fitted with an inflatable gasket to insure gas containment when the

bulkhead is used as a barrier in establishing a gas zone. The gasket is pressurized with 100 psi of nitrogen to withstand mine pressures up to 110 psi.

The bulkheads retract into a bulkhead chamber which also houses the winch and bulkhead controls. The E entry bulkhead chamber is located in the solid E entry rib. The bulkhead chambers are separated from the entries by 100-psi marine doors.

FLEXIBILITY OF UNDERGROUND LAYOUT

The full underground layout of the new workings is shown in figure 2. By selectively closing each of the two explosionproof movable bulkhead, four

partial underground layouts can be realized. These configurations are outlined in table 1, including reference to the particular figure that shows that configuration.

TABLE 1. - Underground configurations

Configuration	Description	Bulkhead position		Figure
		D entry	E entry	
1.....	Full mine.....	Opened.....	Opened.....	2
2.....	Single entry.....	Closed.....	-	18
3.....	Triple entry.....	-	Closed.....	19
4.....	Longwall face, single entry.	Opened.....	Closed.....	20
5.....	Longwall face, triple entry.	Closed.....	Opened.....	21

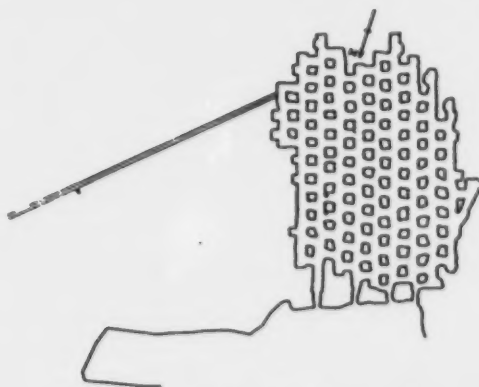


FIGURE 18. - Single-entry configuration.

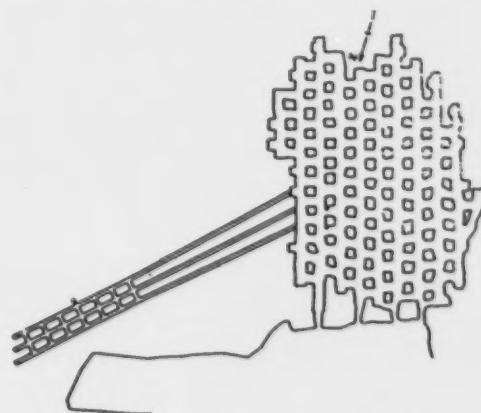


FIGURE 19. - Triple-entry configuration.

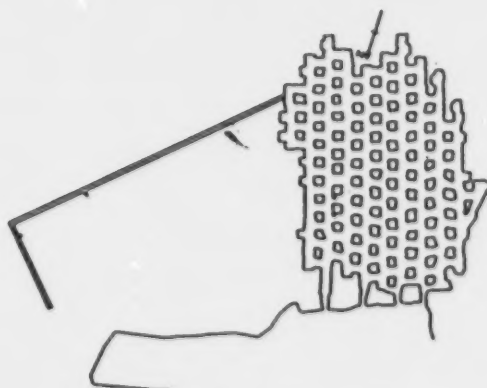


FIGURE 20. - Longwall face-single-entry configuration.

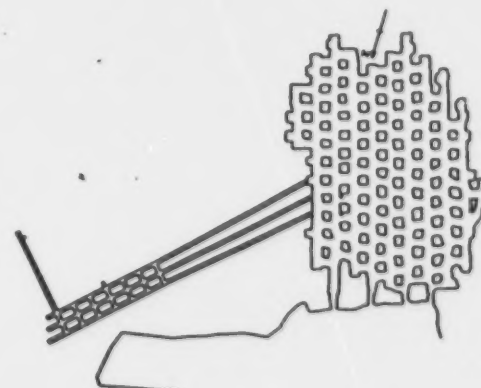


FIGURE 21. - Longwall face-triple-entry configuration.

GAS-MIXING STUBS

There are two gas-mixing stubs in the new workings. They are located at the head of B entry and in the solid rib side of D entry (outby the explosionproof bulkhead) at the positions shown in figure 2. The gas-mixing stubs are separated from the entries by 3-ft-thick reinforced concrete bulkheads designed to withstand 100 psi of static pressure.

The gas-mixing stubs provide for the remotely controlled (from control building) release of natural gas at the mixing stub location. This release can be extended to any point within the mine using appropriate piping. This piping passes through pressure seals in the bulkheads separating the stubs from the entries and through preexisting conduits that bypass the movable explosionproof bulkheads. Gas can be released at controlled rates from 0 to 34 cfm. Gas zones can be developed anywhere within the underground workings using various combinations of the following six barriers: rib, roof, floor, face, explosionproof bulkheads, and polyethylene-wood diaphragms.

Provided at each stub are 2 bundles, each containing 12 gas-sampling tubes. These tubes can be routed to any point(s) in the mine using the same paths as defined for the gas release. The tubes are 3/8-in-OD polypropylene.

VENTILATION SYSTEM

The new workings are ventilated by a four-speed reversible, 100-hp, 60,000-cfm fan located at the top of the ventilation shaft. The fan can be remotely operated from the control building as well as directly from the fanhouse.

The old workings can be selectively ventilated using exhaust fans and ventilation tubing located at portals 3, 2, and 1.

DATA-GATHERING (DG) PANELS

Located throughout the "new workings" of the Lake Lynn Laboratory are 50 DG panels. The locations of these panels are shown in figure 24. Figure 25 is an artist's drawing of such a panel, and figure 26 shows an actual panel.

A DG panel is a permanent instrument box connected to the control room by 15 pairs of wires. The box is recessed into the rib and serves as a fixed location for a static pressure transducer and a flame sensor. There are 110 V and 220 V ac power available at each panel, as well as a voice communications link to the control room.

At each panel there exists the ability to issue control instructions. The devices that can be controlled from a DG Panel include—

- movie (or TV) camera.
- triggered barriers.
- calibration of all instruments from control room.
- operation of grab-sampling probes.
- local ignitions.
- activation of compressed air to purge windows of optical dust probes. Instruments that can be monitored from a DG panel include—
- wall pressure transducers (static pressure).
- infrared phototransistors (flame arrival).
- photomultiplier tubes (flame radiation in visible and ultraviolet).

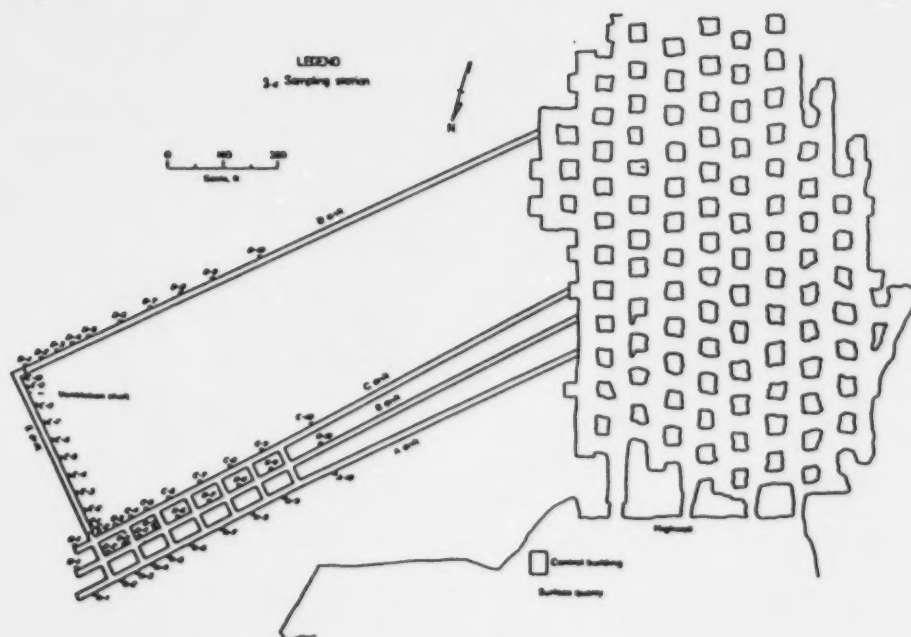


FIGURE 24. - DG panel (sampling station) locations.

- photomultiplier tubes (flame radiation in visible and ultraviolet).
- dynamic pressure transducers (pilot probes and drag probes for velocity measurements).
- optical dust probes (instantaneous concentration of dust in air).
- grab-sampling probes (for gas and dust samples).
- thermocouplers (for gas temperatures).
- three-color pyrometers (for dust cloud temperatures).
- strain gages (for bulkheads).

SENSOR MOUNTING PLATFORMS

There are 38 sensor mounting platforms located throughout the new workings of the Lake Lynn Laboratory. Figure 27 shows the location of these platforms.

A sensor mounting platform is a centrally located rigid structure suspended 3 ft from the mine roof. The structure is retractable and can be "folded" up into the roof. When extended, the platform provides a 1-ft² horizontal working platform upon which to locate hardware for "through" measurements. The platform will be located approximately 3 ft below the mine roof at the center of the entry. Figure 28 is an artist's rendition of a sensor mounting platform.

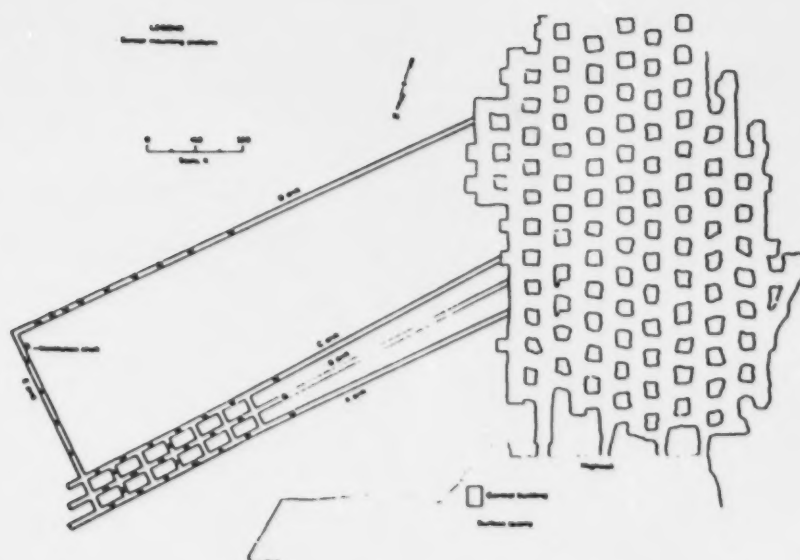


FIGURE 27. - Instrument platform (sensor mounting platform) locations.

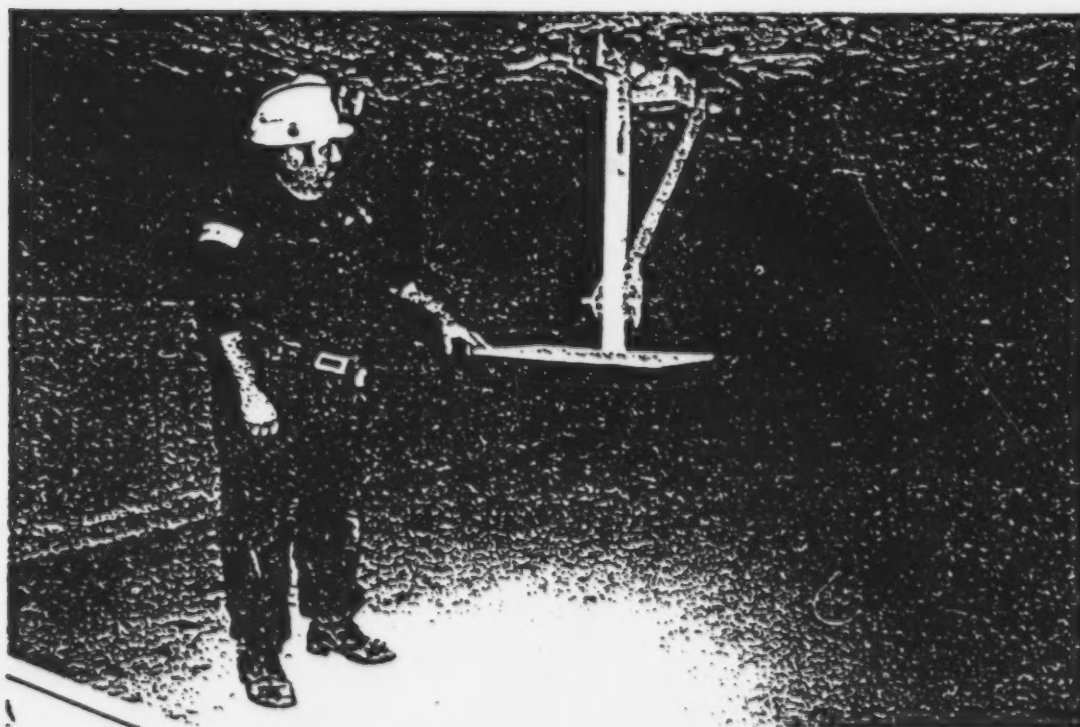


FIGURE 28. - Instrument platform that retracts into the roof of the entries—there are 38 such - platforms installed in the facility.

CONTROL AND DATA ACQUISITION SYSTEMS

DATA ACQUISITION SYSTEM

The Lake Lynn Laboratory is equipped with a computer-controlled data acquisition system (DAS). The sampling rate of the DAS is 3,125,000 samples in an 8-sec interval. There are 132 input channels to the DAS. The system has a storage capability of 4 complete runs (approximately 12 million samples).

There is a dedicated communications link from the Lake Lynn Laboratory system to the PDP 11/34 computer located at the Bureau's Bruceton facility. Onsite interface capability to the Bruceton system is available at Lake Lynn, as is the ability for onsite data reduction (including preparation of plots).

27

GAS ANALYSIS SYSTEM

The gas analysis system has the following features:

- gas analysis (for methane and CO) is performed by a nondispersive infrared analyzer.

- samples are drawn at 8 lpm at a vacuum of 6 in Hg.

- each tube can automatically be individually, selectively, or sequentially scanned.

- the response time, from request for data for receipt of result, is less than 1 min.

- each time a sample is drawn, there is an automatic check for volume flow and vacuum.

HIGH-SPEED ANALOG RECORDERS

The Lake Lynn Laboratory is equipped with three high-speed light beam analog recorders. The recorders can operate with selected chart speeds up to 120 ips. A total of 82 analog signals can be simultaneously recorded.

CONTROL SYSTEM

The following operations can be controlled from the Control-Support Building:

- main fan
- gas release
- shotfire circuits
- gas sampling
- ventilation shaft door

CONCLUSIONS

The Lake Lynn Laboratory presents a flexible environment that will enable researchers to investigate a number of mining health and safety phenomena. The primary area of interest is, of course, fires and explosions. The facility is unique in that it accurately reproduces present mining conditions, including a longwall panel. Its utilization will,

however, extend to virtually all research areas that require isolated surroundings for safe evaluation of new technology such as innovative roof control devices, new explosives, and improved drills. Thus, the Lake Lynn Laboratory is a tool that promises to significantly contribute to the improvement of the health and safety of our Nation's miners.

APPENDIX

TABLE A-1. - Contractors for the Lake Lynn Laboratory

Contractor or Supplier	Description	Time
MAJOR CONTRACTORS FOR THE LAKE LYNN LABORATORY		
Green International, Inc.....	General facility design.....	8/79-10/80
Gilbert Corp.....	Drift driving, installation of movable bulkheads, installation of remote control door, concrete on entry floor.	10/79- 2/81
Solomon & Teslevich.....	Instrumentation and utilities.....	8/80-10/81
Weiss Brothers.....	Highwall construction.....	6/82- 9/82
SUBCONTRACTORS OR SUPPLIERS FOR THE LAKE LYNN LABORATORY		
T. Yezbak & Son.....	Construction of control building, fan building, compressor building, security walls, and fences.	Spring 1980- Fall 1981
Colonial Ornamental Iron Co....	Movable bulkheads.....	5/81
Baldwin Electric.....	Instrument communication and power cable installation.	10/80-10/81
Process Corp.....	Computers ¹	5/81
Dennis Corp.....	Concrete supplier.....	10/80-11/81
Motorola Corp.....	Radio communication system.....	8/81
Tube Turn Corp.....	Remote control door.....	8/80
Honeywell and Bell & Howell....	Analog recorders and data amplifiers..	6/81

¹PDP 11/34 with 96 kw of memory, RP04 disk drive storage units (80 MB), 4 Analogic A/D converters, 13-bit resolution input = +10 V 250-KHz sampling rate, 4 Monolithic external memory units with 256 KB of semiconductor memory computer. Manufacturer: Digital Equipment Corp.

Figure A-1 shows a plan view of the Bruceton Experimental Mine. The mine is a twin-parallel-gallery arrangement. The galleries (main entry and air course) are 1,300 ft long. The cross section is rectangular, 6 ft high by 9 ft wide. Each gallery is lined with concrete and has mine-car tracks layed down the center. Within 600 ft of the face, the following instrumentation is installed:

- static pressure sensors (10)
- dust concentration probes (3)
- light sensors (16)
- dynamic pressure sensors (3)
- pyrometers (3)

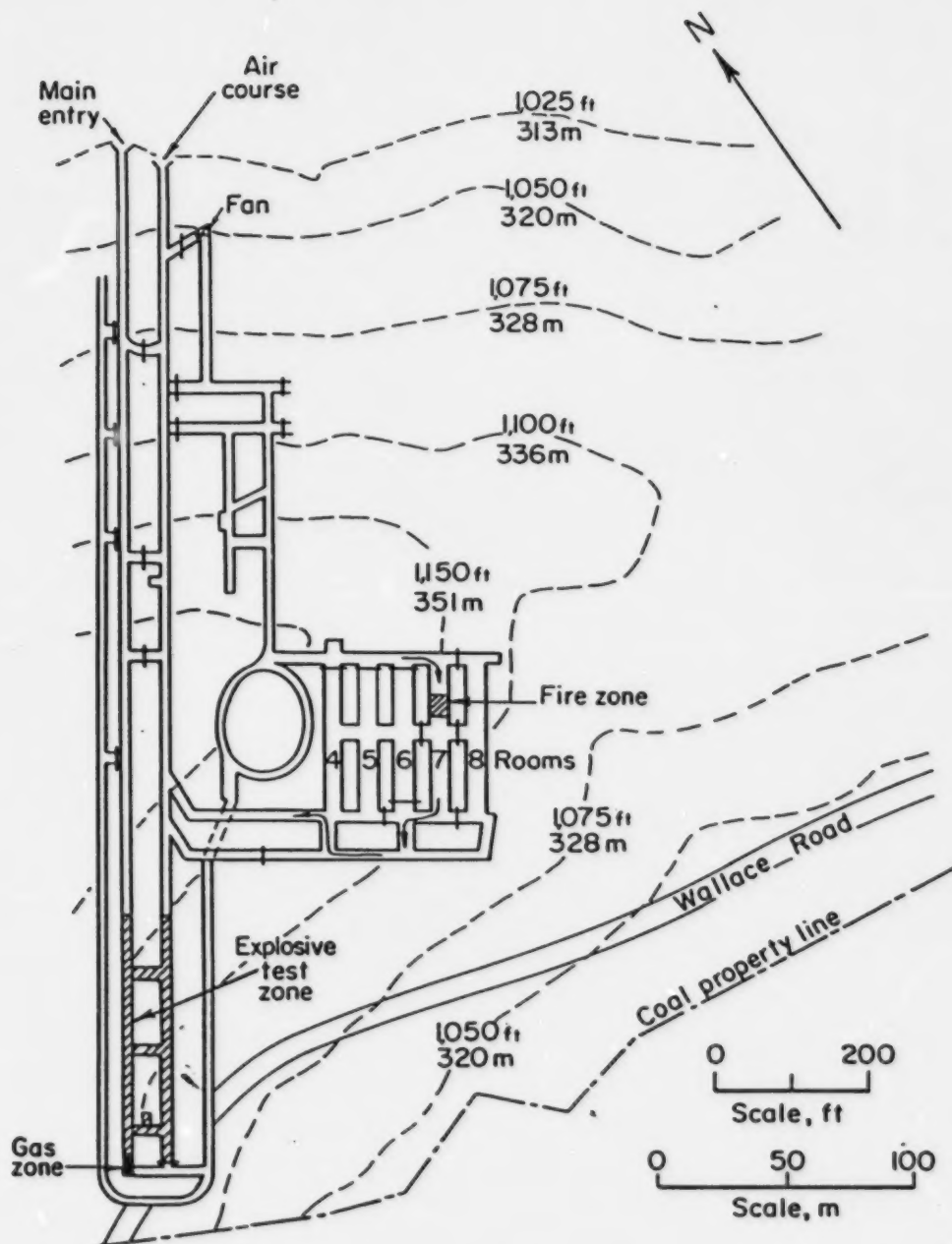


FIGURE A-1. - Plan view of Bruceton Experimental Mine.

Bureau of Mines **RESEARCH**

a summary
of significant results
in mineral technology
and economics



UNITED STATES DEPARTMENT OF THE INTERIOR

Ventilation

Evaluating Ventilation Parameters of Three Coal Mine Gobs

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To better understand the potential of the sealing or ventilating techniques used once mining is completed, a tracer gas, sulfur hexafluoride (SF_6), was used by the Bureau to measure ventilation air patterns and gob volumes in three mines.

Coal mining involves the fracturing and removal of a certain portion of the total in situ coal seam. In an effort to work the seam more completely, different mining methods, such as retreat mining and longwalls, have become common. In room-and-pillar extraction, retreat or second mining is often performed. Coal pillars that remain after the primary mining cycle are systematically removed, causing a controlled caving of the overlying strata. The mine operation then has two options: (1) continue to ventilate the mined-out area, or gob, or (2) seal off the section, isolating it from the main mine ventilation. The gob must either be ventilated or sealed to reduce the possibility of large methane emissions in methane-rich seams, or to prevent spontaneous combustion.

The first mine, which employed mainly longwall extraction techniques, was required to ventilate the gob. To measure gas velocities through the gob, SF_6 was released down a capped borehole into a ventilated gob and sampled for 6 days at several locations around the gob. The total time required for the gas to traverse the gob and enter the ventilation airstream was converted to an average velocity, expressed in feet per minute. One side of the gob appeared to be better ventilated than the other. In this evaluation the borehole location appeared to be a critical factor in

ventilation performance. Multiple boreholes in each panel (which the mine ultimately drilled), or possibly a more strategic location of a single borehole would improve gob ventilation.

The second mine, which used room-and-pillar extraction, sealed its gobs. Because this mine was located in a coal seam prone to spontaneous combustion, gas samples were being taken from two seals in the same small gob. The operator was concerned because sample analyses did not agree. Gas samples taken from each of the two outside seals differed radically, one exhibiting high methane and low oxygen, the other just the opposite. SF_6 was injected behind the right seal, which was displaying ambient air properties. The results of these tests indicated the presence of an extensive roof fall just inby the right seal. This caving was tight enough to separate the volume immediately behind the seal from the rest of the gob. Thus, the mine could not use this seal as a valid sampling point for determining gob gas concentrations.

The third mine, also mining via the room-and-pillar method, had sealed its mined-out gobs. The gob evaluated, located in a methane-rich seam, was very large, with three separate but interconnected panels having a total of 18 seals separating it from the active mine. The coal seam pitched downward so that each set of seals was at a different elevation and had a dissimilar methane concentration behind it. These tests examined the potential interconnection of the gob entries as well as the performance of the section seals. SF_6 was released behind each set of seals on separate days. Results of these tracer gas evaluations showed little connection between the three sections. In addition, the seals themselves were examined for their ability to restrict airflow. Air leakage problems were discovered in one set of seals, which may have caused the methane concentrations behind them to fluctuate in and out of the explosive range.

These evaluations showed that mines having problems with spontaneous combustion or methane emissions in mined-out gob areas can assess the possibility for more serious difficulties in the future. By using a nontoxic, nonflammable tracer gas, sulfur hexafluoride, gas migration related problems can be studied in both ventilated and sealed gobs.

Better Stoppings for Mines With Large Entries

Edward D. Thimons, Technical Project Officer
Pittsburgh Research Center, Pittsburgh, PA

The large entries of many mines, such as oil shale, salt, and limestone, make conventional stopping construction used in mines with smaller openings unacceptable. The Bureau and the Colorado Mining Association jointly sponsored a study to design new or modified stopping concepts for these mines and test the most promising concepts in an oil shale mine with 30-ft-high by 55-ft-wide openings. Five permanent stopping concepts were evaluated in terms of

cost, air tightness, and resistance to blast damage. The following is a description of each concept evaluated.

Pipe and Sheet Pile Stopping.—A stopping is formed by using telescoping 5- and 6-in square section steel tubes, set in holes in the floor, and attached to angle iron anchored in the roof with resin bolts. Panels of 16-gauge corrugated galvanized steel sheets are attached to the tubes using self-tapping screws. All joints and the entire perimeter are sealed with rigid foam.

Brattice and Wire Mesh Stopping.—Damage-resistant brattice (standard brattice panels hung side by side and joined by hook-and-loop seals) is sandwiched between layers of 12-gauge chain link fence. The wire fencing is attached to angle iron anchored to the roof and floor with resin bolts. The edges of the fencing are wired together. The brattice seams and the stopping perimeter are sealed with rigid foam.

Transformable Stopping.—A damage-resistant brattice is converted to a permanent stopping. After the brattice is hung, frames of 6-in channel iron, 12 ft wide, are fabricated on the ground, and one side is covered with 12-gauge chain link fence. These panels are raised against the brattice and anchored to the roof and floor with resin bolts. The chain link fencing is secured at the ribs with masonry nails. The entire stopping is then sprayed with rigid foam.

Muckpile Stopping.—Mined oil shale is placed in the crosscut with a front-end loader and shaped to within 6 ft of the roof with a bulldozer. The 6-ft gap is pneumatically stowed with oil shale of less than 3-in size. Any small remaining gaps at the roof are closed with foam.

Muckpile and Brattice Stopping.—Mined oil shale is piled in the crosscut to within 12 ft of the roof and the remaining opening is closed off with a brattice curtain. The sides and roof are sealed with rigid foam. A 2-ft flap of excess brattice on top of the muckpile is sealed by piling oil shale on it.

Air leakage through the stoppings was measured as a function of the differential pressure across them, immediately after stopping construction and following a full-scale, 1,800-lb face blast about 700 ft from the muckpile and brattice stopping, and about 1,500 ft from the other stoppings. Peak blast air pressures at the stoppings ranged from 2.3 to 4.2 in. water gauge. The blast tore the curtain from the roof on the muckpile and brattice stopping, necessitating repairs before postblast leakage could be measured, the other four stoppings were not damaged.

The preblast and postblast leakage, in terms of what the mining industry considers acceptable, was good for all except the muckpile type stoppings. Preblast and postblast leakage for the other stoppings was about the same. The leakage across the muckpile stopping increased significantly, probably because of continued settling. The high leakage rates for muckpile type stoppings are surprising, especial-

ly since these stoppings are now used in many mines with large openings.

The following tabulation summarizes the construction costs and leakage rates for the five stopping concepts evaluated.

	Cost	Leakage ¹	
		Preblast	Postblast
Pipe and sheet piling	\$8,858	80	80
Brattice and wire mesh	3,018	260	160
Transformable	6,747	320	460
Muckpile	5,789	3,610	5,130
Muckpile and brattice	2,412	2,080	2,170

¹Measured in cubic feet per minute per 1,000 ft² at 0.1 in. water gauge.

In general, the study shows that—

Large size stoppings with low leakage rates can be built at an acceptable cost;

Blasting damage to permanent stoppings can be prevented by locating them at reasonable distances from the blasting face; and

High initial construction costs of some stoppings can be more than compensated for by reduced air leakage and low maintenance costs.

Ventilation of Extended Cuts—Exhaust Systems

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Remote control of mining machines is becoming more common in U.S. coal mines because it offers numerous safety and productivity advantages. Because the remote control unit allows the miner operator to remain outby the machine, mining can proceed to distances of up to 40 ft. To maintain face ventilation during these extended cuts, various ventilation methods compatible with extended cutting were modified and evaluated by the Bureau.

Initial laboratory research focused on mechanical and hydraulically powered ventilation systems both for the mining machine and the shuttle car. The impact on face methane levels of various mining configurations, face airflows, tubing or brattice, roof heights up to 12 ft, presence or absence of shuttle cars, and idle miner time were all considered. The best laboratory tested system was an arrangement of water sprays known as the extended cut ventilation system, which makes use of the directional water sprays that have proven to be an excellent ventilation tool for methane control and the previously developed sprayfan system adopted by over 300 U.S. mines. In the new system, spray blocks pointed inby have been added near the operator's cab, another spray block on the off-operator side points outby and toward the exhaust ventilation system.

Static and dynamic tests using tracer gas were conducted in a full-scale mine model and underground

to measure the effectiveness of exhaust face ventilation for various deep cutting mine and spray configurations. When compared with 10-ft ventilation brattice, the extended cut ventilation system consistently provided better face ventilation at all mining configurations up to and including the 40-ft brattice setback. The system is simple, inexpensive, and extremely mineworthy. Tests show that adequate ventilation is maintained even when one-third of the sprays are plugged. Ventilation brattice setbacks in excess of 40 ft may be possible with this system.

Fire and Explosion Prevention

Computer-Aided Fire Detection and Warning

*William Pomroy and Steven Sampson, Principal Investigators
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Fires in underground mines pose a serious threat to the safety of miners. Contaminated air (CO, CO₂, smoke, etc.) represents the primary hazard. The most effective defense against this hazard is early fire detection and timely evacuation of the mine.

The Bureau is studying the use of a computer-aided fire detection and warning system to enhance the decisionmaking information derived from conventional fire detection devices. The system comprises three major elements: a network of underground fire detectors, a data communication system linking the detectors to the surface, and a computer programmed with appropriate process control and data analysis software.

This research is a phased effort. The first two phases involved laboratory and in-mine evaluation of fire detection devices for their suitability for extended usage under the harsh environmental exposures encountered underground. Research has resulted in improved interference filters, transient suppressors, environmental enclosures, sample pumps, and other electrical and mechanical devices. These upgrades have significantly reduced detector errors and failures in the field.

The third phase involved data communications to relay detector outputs to the surface. The resulting system is configured in a telemetry loop, thereby simplifying installation and minimizing system costs, while providing a redundant signal path capability. The communication system is operated and supervised by a microcomputer functioning in a process control mode. As a result, redeployment or expansion of the detection network can be accommodated by simple software changes in the control computer.

The fourth phase involves data analysis software to interpret the signals received from the underground detectors. The goal is to integrate detector outputs (products of combustion such as CO, CO₂, and/or smoke) with ventilation flow data to determine the location of a fire within a complex mine network. An algorithm to achieve this goal has been devised. The technique involves the use of a specialized com-

puter simulation model which calculates the time dependent spread of combustion products throughout a mine. Using this model, a multidimensional array is created and stored for later reference. This array consists of an ordered listing of every possible combination of fire location and combustion product transport time to each detector. In the event of an actual fire, the pattern of measured combustion product arrival time differentials is compared to the array using standard array scanning techniques, with the actual fire location indicated by the closest match between measured and simulated arrival time patterns. This algorithm has been validated by modeling the ventilation flows in an underground metal mine. Software preparation incorporating this algorithm is underway.

The fifth and final phase of this research will involve field validation tests of a complete system in an operating underground mine. Three mines are presently under consideration for the in-mine test phase—an Arizona copper mine, an Idaho silver mine, and a New Jersey zinc mine. These mines are presently being used as field test sites for the detector evaluations.

Improved Conical Cutter Bit Design and Orientation To Minimize Frictional Ignition and Maximize Bit Life

*Aldo Furna, Principal Investigator
Pittsburgh Research Center, Pittsburgh, PA*

Frictional ignitions continue to be a severe problem in U.S. coal mines. For the years 1983, 1984, and 1985, respectively, 51, 57, and 81 frictional ignitions were reported by the Mine Safety and Health Administration. Continuous mining machines, using conical bits, account for 39, 38, and 69 of these frictional ignitions, respectively, any one of which could have initiated a catastrophic explosion. One mining company experienced an increase from 20 frictional ignitions in 1984 to 51 in 1985. This dramatic increase prompted a joint effort by the Bureau, the mining company, and a tool company to minimize frictional ignition as well as maximize bit life.

Previous Bureau research had shown tungsten carbide to have a much lower ignition potential than common alloy steel bit shank materials and had resulted in the Bureau's prototype capped carbide or "mushroom" bit. As compared to the standard insert bit design, the carbide cap has the advantages that the cap overlays the entire tip of the bit, protecting it from impact, wear, and abrasion during the cutting process. Several manufacturers of conical bits are now producing capped bits commercially.

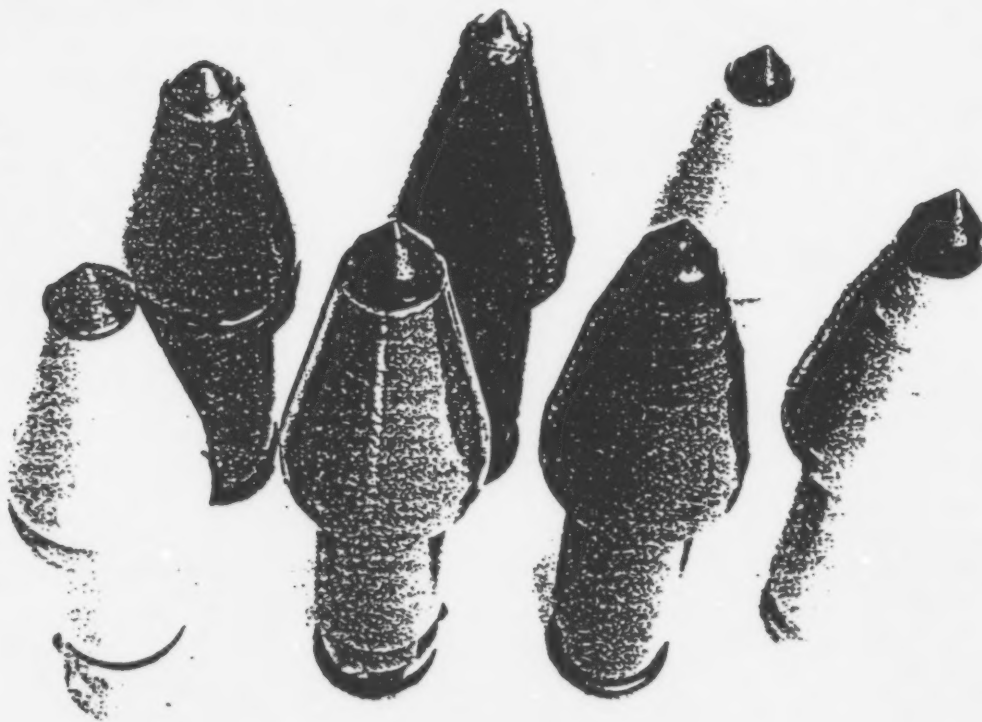
Another important factor in preventing frictional ignition is proving to be the angle at which the bit attacks the rock. Continuing Bureau laboratory tests with the capped bits have shown that increased attack angle, that is, the angle between the bit axis and the sandstone surface, can reduce the probability of

ignition. The tests were conducted with frozen (non-rotating) bits cutting into sandstone in an atmosphere containing 7 pct methane in air. The total number of strikes to obtain ignition was counted, each strike equaling 1.95 linear feet of stone cut. At an attack angle of 50°, the average number of strikes for ignition was 20. At 60°, 60 strikes were required. A further increase of the attack angle to 67°, raised the number of strikes required for ignition to 90.

To conduct field tests, it was necessary to replace the cutting head of a continuous miner, which required consideration of the added forces on the bit, bit holder, and cutting head, and the greater torque requirements due to the increased attack angle. The number of bits was reduced from 104 to 77, and the

attack angle set at 57°. Initial in-mine tests confirmed laboratory tests, except for a 25 pct fracture rate of the carbide cap. Modifying the carbide tip by increasing the size of the stem, improving quality control in the manufacturing process, and improving the technique for brazing the tip into the shank greatly increased bit life.

Results are very encouraging. No ignitions have been reported in 8 months of operation. Bit life has been increased by about 400 pct and productivity by 28 pct. Three machines have been retrofitted with the new bits and the mining company plans to retrofit all its continuous mining machines with the safe, more productive cutting system.



Conventional cutter bits with small tungsten carbide inserts (back); Bureau "mushroom cap" bit design and commercial versions of Bureau design (front). The cap overlays the entire tip of the bit and protects it from impact, wear, and abrasion during the cutting process.

Remote Detection of Methane

*Charles D. Litton, Principal Investigator
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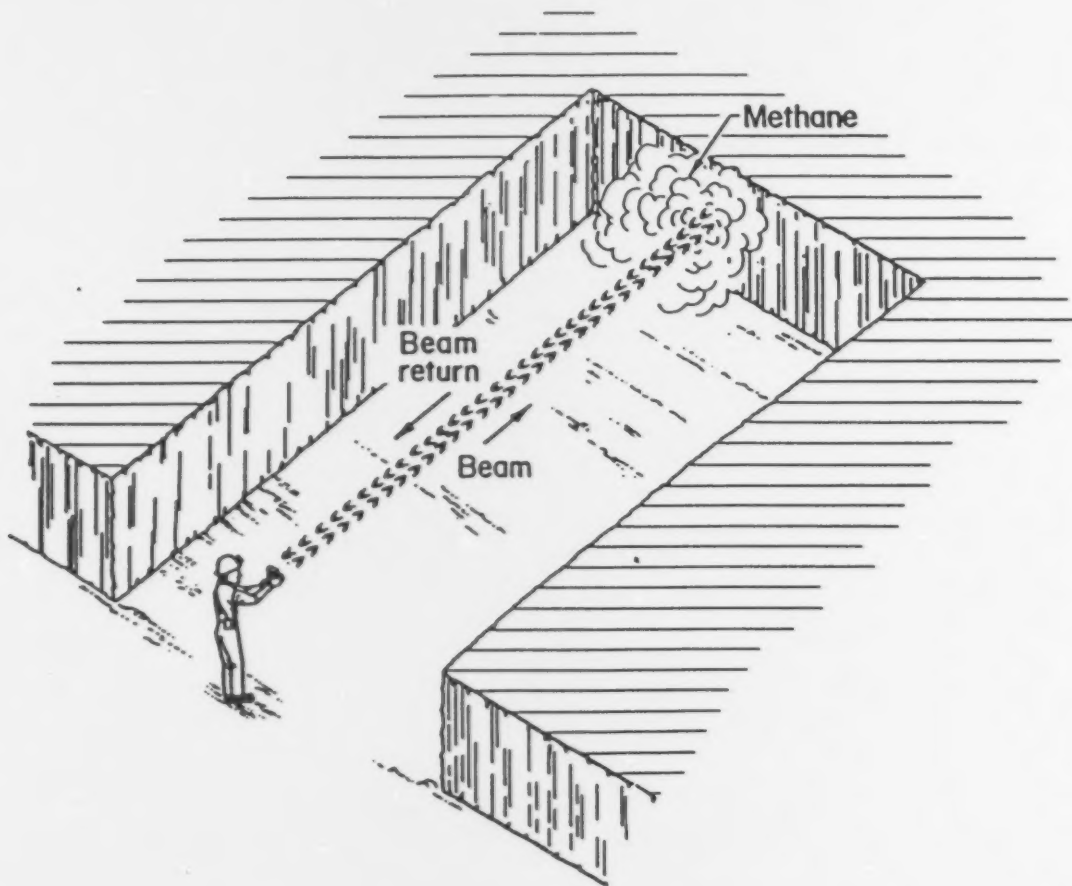
State and Federal regulations require frequent measurements to verify that safe methane concentrations prevail in underground coal mines.

Ventilation control is the primary means of maintaining safe methane concentrations. In the immediate face area, where the highest methane levels occur, methane measurements are required every 20 min during active mining. To perform these measurements, temporary roof supports must be erected to allow a miner to reach the face where a hand-held methanometer is used to make these measurements.

This procedure is not only time-consuming but also extremely hazardous. To facilitate the measur-

ing process and reduce miner exposure to roof falls, a prototype optical device has been developed that can measure methane remotely from distances up to 40 ft. The device utilizes the ratio of two signals in the infrared region which are reflected from the coal face, rib, or roof. One signal is preferentially absorbed by methane, while the other is not. The ratio of the two signals determines the average methane concentration in the face area.

The prototype detector has also been successfully tested at the Bureau's Lake Lynn Laboratory. Instantaneous responses were obtained both for methane in the ventilating airflow and for methane layered near the roof. Conventional methanometers required about 5 to 25 s to respond to the methane in the ventilating airflow and did not respond at all to the methane roof layer. Private companies have expressed interest in commercial adaption of the detector.



A prototype optical device has been developed to measure face methane concentrations from distances as great as 40 ft.

Fire Tests of Conveyor Belting

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Many underground coal mines use extensive conveyor belt systems to transport coal out of the mine. The belts, which are constructed of rubber or polyvinyl chloride (PVC) formulations, are required by Federal regulations to be fire resistant. The current approval test for fire resistant belting is a small-scale fire test that uses 1/2-in-wide by 6-in-long samples. This test does not adequately assess the flammability of the belting under actual underground mine conditions.

To better understand the flammability characteristics of conveyor belting and evaluate its fire hazards, the Bureau is conducting full-scale belt fire tests in a recently constructed surface gallery at the Bureau's Lake Lynn Laboratory. A 90-ft-long, arched roof fire tunnel is coupled to a large (120,000 ft³/min) ventilation fan in which airflows can be varied from 100 to 2,000 ft/min. The inside of the 13-ft-wide by 8-ft-high

tunnel is lined with ceramic blanket insulation. The tunnel has a gallery instrumented with video cameras, thermocouples, airflow probes, and products of combustion sensors for gases and smoke, all of which are used to monitor a 70-ft-long conveyor belt structure with 5-in-diameter rollers that supports the belting in the tunnel. Test data are recorded via a sophisticated data acquisition system linked to the main Lake Lynn computer.

The initial objective of the full-scale belt fire tests is to evaluate the effect of airflow on fire hazards. This information is vital to the specification of maximum airflows in mine belt entries on intake air which then ventilates working areas. Thirty- to fifty-foot lengths of belting are placed on the top rollers of the belt structure and ignited by a liquid fuel tray located below the upstream edge of the belt sample. Flame propagation rates and downstream smoke and gas concentrations are monitored at airflows of 300 and 800 ft/min. Preliminary results with rubber and PVC conveyor belting indicate less downstream smoke and gas concentrations at the higher airflow.



Full-scale fire test of a conveyor belt at an airflow of 800 ft/min. Full-scale tests are necessary to assess the flammability of belting under actual underground mine conditions.

Diesel-Discriminating Mine Fire Sensors

*Charles D. Litton, Principal Investigator
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In mines that use diesel-powered equipment, the diesel exhaust products (CO , CO_2 , smoke) may generate high background levels that cause product-of-combustion fire sensors to give false alarms. High false alarm rates reduce miner confidence in fire detection systems. Increasing alarm thresholds in order to reduce false alarms also severely reduces the effectiveness of the system, particularly when little or no diesel operation is present. To address the problem of false alarms without sacrificing sensitivity, the Bureau is developing a re-pyrolysis technique to use in conjunction with the Bureau's submicrometer particle detector.

Research has shown that fire smoke particles will re-pyrolyze when passed through a short, heated metal tube, increasing the smoke particle number concentration significantly. Diesel smoke particles, upon passage through the same heated tube, are unaffected. By measuring the difference between re-pyrolyzed and unpyrolyzed smoke levels, high sensitivity to fires can be maintained even in the presence of high diesel background levels.

The use of this technique is to be studied in a series of full-scale tests at the Bureau's Lake Lynn Laboratory. An alternative technique for discrimination utilizing the ratio of CO to NO levels will be tested concurrently. This approach relies upon the fact that NO is produced from diesels, but not from fires. If the CO-NO ratio remains constant, then it is possible to detect a fire above some high diesel level of CO by subtracting out the CO expected on the basis of NO that is measured. The potential for this technique depends upon the relative stability of the CO-NO ratios during typical mining operations.

Methane Control

Longwall Gob Gas Control Using Cross-Measure Boreholes

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Prior to 1970, ventilation was the primary method of controlling explosive methane gas in gobs (mined-out areas of underground coal mines) in the United States. As mining depth increased, gassier coalbeds and surrounding strata were encountered, and acceptable methane levels in the bleeder entries could not be maintained by ventilation alone. Consequently, surface gob holes were introduced in the 1970's as an auxiliary means of gob gas control. They have proven highly effective and are commonly used today by the mining industry. However, surface gob holes cannot always be drilled because mining may be under populated areas, topography may be too

severe, or access to private property may be denied. An alternative method of controlling gob gas was needed that was independent of the mine ventilation system and surface right-of-way problems.

In Europe, small-diameter boreholes (cross-measure boreholes) are drilled from underground locations into the roof strata above a longwall. Suction is applied to these boreholes to draw the methane from the strata being fractured by the longwall operation. These holes are connected to an underground pipeline that transports the methane to the surface. This method is independent of the mine ventilation system and free of surface right-of-way problems. For the past several years, the Bureau, in cooperation with the mining industry, has been experimenting with this technique. Results have been encouraging.

Borehole length, spacing, and angles (vertical and horizontal), location of methane-bearing strata in the roof, pipeline diameter, and operating parameters of the surface pumping facility are important factors that need to be considered in designing a cross-measure borehole system. The quantity of methane produced by a longwall mining operation varies from about 1 MMcf/d where overburden is 650 ft to 17 MMcf/d where overburden is 2,500 ft. Experience shows that 71 pct of the methane produced by a longwall mining operation can be captured by the cross-measure system. Thus, the surface pumping facility must be designed to cope with these large quantities of methane. Since methane flow from a cross-measure borehole is directly dependent upon the partial vacuum at the hole, the pressure drop in the underground pipeline should be kept small to keep the partial vacuum at the hole as large as possible.

Borehole spacing depends upon the permeability of the fractured strata and operating parameters of the vacuum pumps. Because little is known about gob permeability, which may be affected by local geologic conditions and overburden thickness, borehole spacing is best determined from underground tests. Bureau studies show that the spacing should be variable. Along the first 600 to 700 ft of the panel, the boreholes should be spaced about 100 ft apart to capture the large quantities of methane that are released and to prevent methane from entering and overloading the return air system. Thereafter, a 200-ft spacing appears adequate.

Because little is known about the migration behavior of methane in the gob or the inflow of gas into a cross-measure borehole, gas pressure differentials associated with the flow of gas into boreholes were calculated for two widely separated cases and then compared with field data. In the first case, gob gas is assumed to flow into the borehole only near the pillar line with the remainder of the hole in the gob nonproductive. In the second case, gob gas is assumed to flow into the borehole uniformly along the length of the borehole in the gob. In most instances, the calculated pressure differentials for the first case match the field data, indicating that borehole length can be reduced from 280 to 140 ft, which makes the

cross-measure system more cost effective. Additional experimentation is necessary to verify these calculations.

Cost comparisons between the surface gob hole and cross-measure borehole systems of controlling methane during longwall mining indicate that the cross-measure system is more cost efficient where overburden exceeds about 1,400 ft; where overburden is less than 1,400 ft, the surface gob hole system is more cost effective. Cost comparisons were evaluated for sites located in central Pennsylvania (650-ft overburden), northern West Virginia (1,000-ft overburden), southern Virginia (1,800-ft overburden), and northern Alabama (2,000-ft overburden). In southern Virginia and northern Alabama, the costs for a surface gob hole system for controlling methane during mining are 53 and 86 pct, respectively, higher than a cross-measure system.

The cross-measure borehole technique is considered a viable method of controlling gob gas during longwall mining, provided the entries are maintained and supported during the life of the retreating longwall. Following the research conducted in a mine with overburden of about 650 ft, the Bureau is seeking cooperation from the mining industry in conducting tests where overburden is 1,500 to 2,500 ft.

Lowering Methane Concentrations Around Longwall Shearers

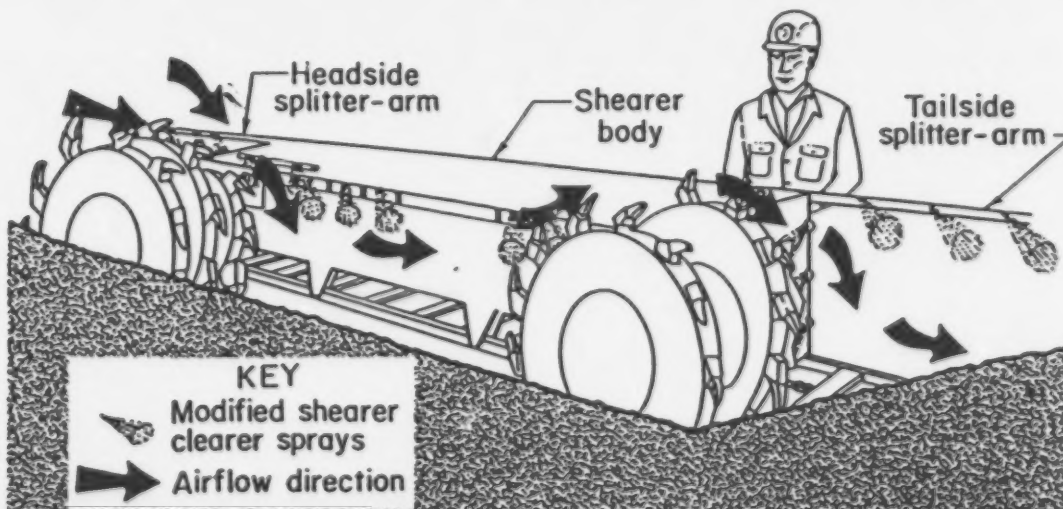
Andrew B. Cecala, Principal Investigator
Pittsburgh Research Center, Pittsburgh, PA

Methane ignitions remain one of the most serious hazards facing the coal mine operators, as evidenced by the number of coal mine fatalities in recent years

due to methane ignitions. The significant quantities of methane liberated during a single pass of a longwall shearer are a major concern to mine operators. Bureau research has shown that methane ignitions can be prevented either by controlling the ignition source, monitoring methane levels and shutting off power when an explosive level is detected, or diluting the methane gas around the shearer to the nonexplosive range.

The approach investigated in this case was to lower the methane levels around the shearer by directing more of the available air along the face and into the poorly ventilated zones around the shearer body. The cross sectional area of the shearer body prohibits much of the ventilating air from sweeping the areas around the head and tailside drums where methane is emitted. Two techniques have been evaluated to direct additional ventilating air into these zones to dilute the methane. To address the entire longwall mining cycle, the use of a walkway curtain during the headgate cutout has been combined with the modified shearer clearer system used for the remainder of the cutting cycle. Together, these two techniques can significantly lower methane concentrations around the shearer for the entire mining cycle at a low cost.

The modified shearer clearer system supplies additional air to the poorly ventilated zones around the shearer. The shearer clearer, as originally designed for dust control, uses a series of strategically located water sprays mounted on the shearer body. In the modified shearer clearer, three sprays have been added to the returnside splitter arm, shearer body interface, and two sprays have been placed at the headside on the corner of the shearer body. Both sets of sprays help to ventilate the face side of the shearer body, especially the zone behind each cutting drum.



The airflow pattern using the modified shearer clearer technique forces additional airflow toward the face, which dilutes methane concentrations to the nonexplosive range.

In a previous field study, the highest methane levels recorded on a longwall face occurred during the headgate cutout, because the intake air cannot make a 90° turn at the longwall headgate, and most of the ventilating air flows back towards the gob for the first 8 to 10 supports. As a result, the airflow along the face and over the machine is insufficient to dilute methane liberated during the headgate cutout. Installation of a walkway curtain forces this air towards the face, where it is needed. The curtain should be located across the walkway near the third support, extending from the support legs to the spillplate and reaching from the roof to the floor. The curtain need only be in position during the cutout, and should be tied up during the remainder of the pass. By installing a walkway curtain, the airflow to the face can be significantly increased.

Both of these techniques were evaluated in a full-scale longwall gallery. The recorded reduction in the methane concentration around the shearer was approximately 73 pct when using the modified shearer clearer system and approximately 60 pct when using the walkway curtain during the headgate cutout. By using the walkway curtain during the headgate cutout and the modified shearer clearer for the remainder of the cutting cycle, methane levels can be lowered significantly and the probability of face ignitions reduced.

Methane Model

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To facilitate control of the explosive gas, methane, in coal mines, computer programs are being developed that will predict, as mine planning tools, the methane emissions into mine workings and the gas-production potential of various types of methane drainage systems. The latest model incorporates dual phase (water and gas) flow through the coalbed. One of its best features is its ability to run with little or no user input. There are four base-case coalbeds for the user to choose from: Pittsburgh, Pocahontas, Blue Creek, and Mary Lee. There are default values for the coalbed properties and other parameters which the user may specify. Other important features of the model include optional nonuniform computational grid spacings in the plane of the coalbed, the effects of horizontal and vertical gas drainage boreholes on methane flows into a mine opening, and the simulation of an advancing mine face.

Although the two-dimensional version of the program is still being debugged, gas pressure profile curves have been generated by the one-dimensional model and compared with observed values for the Pittsburgh and Pocahontas Coalbeds. Absolute permeability of the coalbed was selected as the chief variable parameter. In general, the computer-generated curves were in close agreement with the observed values. Once the critical coalbed parameters

have been correctly estimated, the model can be used to determine mine face emissions during mining, methane production rates from horizontal and vertical borehole drainage programs, and the effects of drainage programs on methane flows during mining.

Bureau of Mines

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a summary
of significant results
in mineral technology
and economics



U.S. Department of the Interior



Bureau of Mines

Life Support Technology

At the turn of the century, fires and explosions in the Nation's coal mines routinely killed hundreds—sometimes even thousands—of miners each year. Although the Bureau has done much in its 77-year history to make mines safer, mine disasters still happen. As recently as 1984, for example, a fire at the Wilberg Mine in Price, Utah, cost the lives of 27 miners.

Studies of mine disasters show that most miners initially survive a fire or explosion. Trapped in an atmosphere that provides insufficient oxygen or that's filled with smoke and toxic gases, they may die before rescuers reach them.

The Bureau's life support research program develops technologies and equipment to increase the chance that miners will survive and escape after an underground mine disaster. This effort has recently focused on improving the breathing devices now used by miners and mine rescue teams.

Emergency breathing devices—known in the industry as self-contained self-rescuers—supply miners with oxygen for 1 hour, giving them a chance to escape from the mine. These devices consist of an oxygen source, an absorbent to remove carbon dioxide from exhaled air, and a breathing bag to store that air in until it is inhaled again. Hoses connect these components.

Coal mine operators are required by law to equip all underground mine workers with self-contained self-rescuers. Because of the size and weight of the units now available, most miners are reluctant to wear them on the job. If miners don't wear the devices, mine operators store them near the worksite.

Fires and explosions in underground coal mines, however, typically expose miners to air containing toxic levels of carbon monoxide. Breathing such air can cause miners to lose consciousness in as little as 4 to 60 seconds. Workers trapped underground may have less than a minute to get to and put on their breathing devices.

The Bureau has developed a new self-rescuer that provides the required 1-hour oxygen supply, but that is small enough

and light enough to be worn while the miner is working. The new device, which can be attached to the miner's belt, weighs 4 pounds—half as much as the units now available.

Scientists were able to make the needed size and weight reductions after studying the different physiological stresses that people experience when breathing with a respirator. A better understanding of how carbon dioxide, breathing resistance, and air temperature affect the body provided a basis for redesigning the self-rescuers.

That research also helped the Bureau improve the breathing devices used by mine rescue teams. Known as rescue breathing apparatus, these devices weigh about 35 pounds and provide a 2-hour oxygen supply. Carried on the back, they limit the mobility of rescue team members, particularly those working in "low coal" conditions where roof clearance may be 3 feet or less.

The Bureau successfully reduced both the weight and profile (how far out the equipment extends from the wearer's back) of the rescue breathing device. The new apparatus, which weighs 22 pounds, includes other improvements as well. Reduced breathing resistance and cooler inhaled air will make breathing easier and more comfortable for rescue workers. The possibility of toxic air leaking into the breathing device has been significantly decreased, if not eliminated.

Bureau scientists have also designed a new rescue team helmet for use with the lighter weight breathing apparatus. The new helmet provides better head protection and replaces the hardhat, breathing apparatus face piece, cap lamp, and communication system now worn by rescue team members.

The new breathing devices developed by the Bureau will be tested and certified for use by the National Institute for Occupational Safety and Health—the Federal agency that sets performance standards for respiratory equipment used by miners, mine rescue teams, firefighters, and other workers whose jobs expose them to toxic air.

Human subjects are usually used to conduct certification tests. Human performance, however, varies from day to day and from person to person, making it difficult to quantitatively evaluate breathing devices.

The Bureau has developed breathing and metabolic simulators that provide more accurate testing of respiratory protective devices. The Bureau's metabolic simulator, which represents the most advanced machine of its type, eliminates the uncontrollable variables involved in human testing. The Bureau plans to recommend that the Federal Government change its testing and certification regulations based on these advances.

The Bureau has made significant progress in ensuring that the best possible technology is available to help miners and mine rescue teams in an emergency. Life support technology may prove beneficial to the Nation in other ways as well.

The Navy and Federal Aviation Administration (FAA) are among the Government agencies that have tapped the Bureau's expertise in testing respiratory devices. The Bureau recently helped the FAA prepare design specifications for an emergency breathing device that would allow flight attendants on commercial airliners to move about the cabin during a fire or depressurization. The stationary oxygen-enrichment devices now available make it difficult for crew members to deal with airborne emergencies.

The Air Force, Coast Guard, and Federal Emergency Management Agency (FEMA) have cosponsored the Bureau's work on improving the rescue breathing apparatus. The Air Force and FEMA are interested in firefighting applications, particularly in atmospheres containing toxic chemicals. The Coast Guard is concerned about protecting workers involved in handling toxic spills.



The introduction of the self-contained self-rescuer (SCSR) to underground coal mines has significantly improved the chance of survival in the event of a fire. Ongoing Bureau research in this area seeks to reduce the size and weight of SCSR units and to improve their ability to perform after extended storage and carrying in a mine.

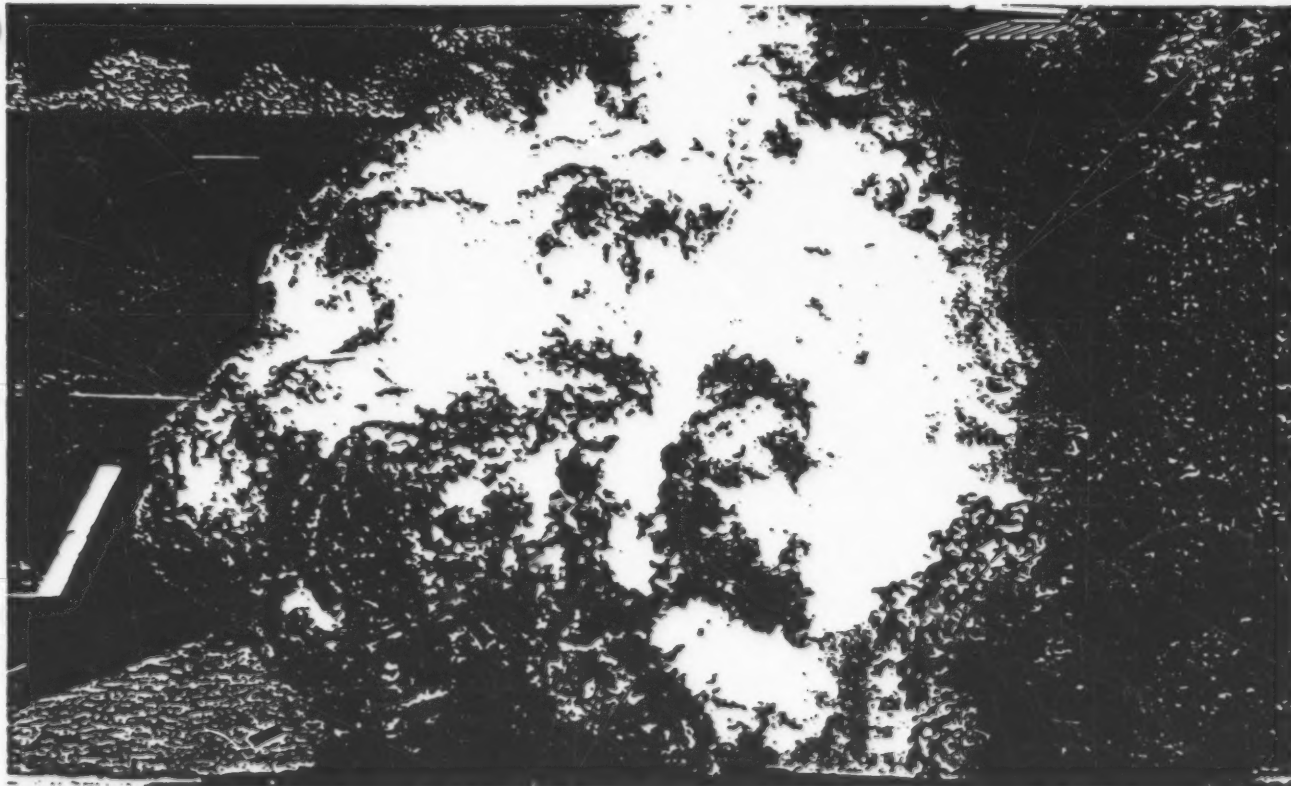
sheathed explosive charges in underground coal mines. More than 250 sheathed charges were fired in flammable atmospheres with no ignitions of the atmospheres. Tests in mines showed that these charges make it safer and less costly to clean up material from roof falls that cover mining equipment or block airways and haulageways. The Bureau is working closely with the Mine Safety and Health Administration to revise Federal regulations and classify sheathed charges as permissible explosives—explosives that can be used in flammable atmospheres.

Bureau explosives experts have worked closely with the Department of Transportation, the U.S. explosives industry, and the United Nations to develop a new international classification system for explosive materials. At present, it is difficult to import and export explosives and explosive articles because testing conducted for U.S. classification may not be recognized in another country.

The new United Nations classification system solves this problem by providing a procedure for developing internationally accepted explosive classifications. The new system categorizes explosive substances and articles according to the risk involved. It provides a common ground for comparison and defines the relative risks.

The Bureau helped develop tests and procedures for the new system. U.S. participants in this effort want to ensure that the new classification system provides for the safe transport of explosives and explosive articles without imposing undue hardship on the explosives industry. The Department of Transportation is considering adopting the United Nations system.

Preventing disasters. Explosive gas mixtures, frictional sparks, spontaneous ignition, flammable materials, and electricity provide all the ingredients for fires or explosions. Most of those ingredients are present in underground mines.



The power and devastation of a mine explosion is seen in a controlled coal dust explosion at the Bureau's safety research coal mine, Bruceton, PA.

Although the Bureau's research has helped reduce the number of fires and explosions that occur in the Nation's mines, it is working to reduce even further the deadly possibility of a mine fire or explosion to an absolute minimum.

Scientists are studying the physical and chemical phenomena involved in dust and methane explosions and perfecting instruments to monitor dust accumulations and methane concentrations. They are also developing and testing automatic systems for detecting and fighting fires ignited by mining machines. Coal dust is produced during normal mining operations, at conveyors and transfer points, and by the movement of personnel and machines. The mine's ventilating air currents can pick up float dust—extremely fine coal dust particles—and carry it into the return airways where it settles on other surfaces. In an explosion, this flammable dust becomes airborne and adds to the explosion.

Covering deposited float dust with inert (limestone) rock dust makes it nonflammable. However, if a thin, fresh layer of coal dust is deposited on top of an otherwise adequately rock-dusted surface, the new layer can be skimmed off by a relatively weak methane-air explosion. To comply with mine safety regulations, mine operators often place rock dusters in the returns to periodically disperse rock dust into the return airways. However, since little information is available concerning float dust deposition rates in U.S. mines, operators must rely on visual inspections to estimate the frequency with which fresh rock dust should be added. As a result, mine operators apply rock dust excessively in some areas, and inadequately in others.

The Bureau has developed a dust accumulation meter to monitor the amount of airborne coal dust deposited near the face, belt transfer points, and other areas. The meter works by distinguishing between the way coal dust and rock dust reflect light. Preliminary tests show that the optical reflectivity of light from surface layers of either rock dust or coal dust, or coal dust or rock dust, can be used to measure the accumulation of explosive dusts. The meter promises to give mine operators a safe, easy

way to determine when rock dusting is needed to control potentially explosive accumulations of coal float dust.

To ensure against unsafe methane concentrations in underground mines, State and Federal regulations require mine operators to measure methane concentrations in the face area every 20 minutes. Miners now make these measurements using hand-held instruments, standing directly at the face, often under temporarily supported roof.

As an alternative to this time-consuming, hazardous practice, the Bureau has developed an optical device that can measure methane concentration from as far away as 40 feet. An infrared light source emits two signals, one of which is preferentially absorbed by methane. The ratio of the signals, reflected back to the detector, gives the average methane concentration at the reflecting surface. Scientists evaluated the methanometer in two series of full-scale tests that simulated methane emission and accumulation at a ventilated working face. The device accurately measured the average methane concentration within the simulated face area.

The Bureau successfully field-tested a prototype fire warning system that uses the transmission and reception of a through-the-earth electromagnetic signal. The signal alerts miners by setting off a light or audible cue from a microreceiver mounted on and powered by their cap lamp batteries. The system is lightweight (about 6 ounces), easy to carry, and inexpensive to make.

The warning signal is activated by generating a magnetic field about a large loop or line transmitting antenna. The magnetic field can penetrate mine rock for distances great enough to alert miners even if they are widely scattered or in remote parts of the mine.

About 90 percent of U.S. underground metal and nonmetal mines are less than 3,000 feet deep. Initial tests suggest that signals can be transmitted through mine rock to this depth. Scientists plan to conduct additional tests of the fire warning system, transmitting signals through different types of rock and at different frequencies and power levels.

**A SUMMARY OF RESEARCH
IN PROGRESS DURING FISCAL YEAR
1988**

OCTOBER 1, 1987 TO SEPTEMBER 30, 1988

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RESEARCH DIRECTOR**

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MINE SAFETY SYSTEMS

Lightweight, Vented Explosion-Proof Enclosures

Explosion-proof enclosures constructed according to current regulations (CFR 30, Part 18) are heavy, bulky, and difficult to access for routine inspection and maintenance. For several years, the Bureau has been pursuing the concept that venting these enclosures would significantly reduce the pressures from methane-air explosions that they must withstand; this would make it possible to use lighter, thinner walled, and less costly construction, as well as nonmetallic, corrosion-proof materials; routine inspections would be less onerous. Under a cooperative agreement with Rade Koncar of Yugoslavia, the Bureau has been exploring the use of stainless steel foam (RETIMET) as a flame arresting vent material. A major objective is to develop enclosures for high-voltage permissible load centers. In FY88, activity will center around large-scale cooperative testing of RETIMET. Work in FY87 showed that RETIMET is a good flame arrestor for methane-air explosions, but there is some concern that flame paths could exist in the foam due to voids or nonuniformity. Several nondestructive methods for evaluating flame ar-

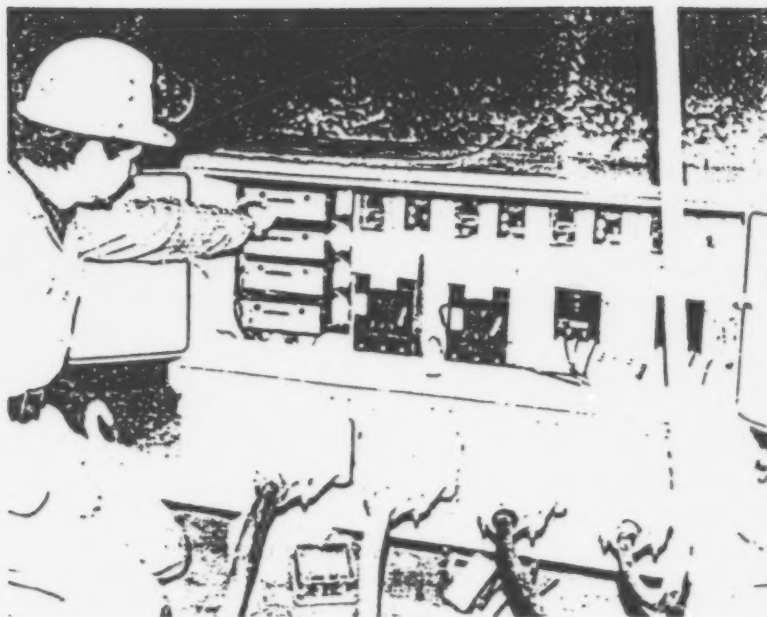


Stainless steel foam (RETIMET) to be evaluated nondestructively for use on vented enclosures

resting properties will be tried and the best test method will be selected for future use. Methods to be evaluated include use of pulsed eddy currents, light penetration, radiography, localized flow measurements, thermography, and ultrasonics. Once a suitable test method has been identified and calibrated to known flows, a device for routine testing will be developed.

Grounding and Ground Fault Protection

One of the major hazards associated with mine power systems are small ground fault currents in the milliampere range that cause sudden death due to ventricular fibrillation. The grounding phase protective devices now mandated in underground mines, although in compliance with Federal regulations, are typically in the ampere range, considerably in excess of such small lethal leakage currents. Increasing the sensitivity of these electrochemical devices results in nuisance tripping of the mine power system. For several years, the Bureau has been researching the concept of a sensitive ground fault relay (GFR) that identifies and interrupts these hazardous currents, while ignoring motor startups, cable charging capacitances and common-mode currents. The result has been a series of GFR's that detect leakage currents in the milliampere range and interrupt those sufficient to kill a human. Their implementation does not require major alterations in the existing power systems; present low voltage relays and grounding resistors are simply replaced by sensitive GFR's and high ohmic resistors. In FY88, a prototype relaying scheme will be fabricated to eliminate the need for coordination in ground fault detection on radial power systems. Efforts will continue to locate cooperative mines to demonstrate AC and DC GFR's. Initially, relays will operate event counters. Following a satisfactory period of performance, a high ohmic grounding resistor will be installed, with ground fault protection exclusively provided by sensitive GFR's.

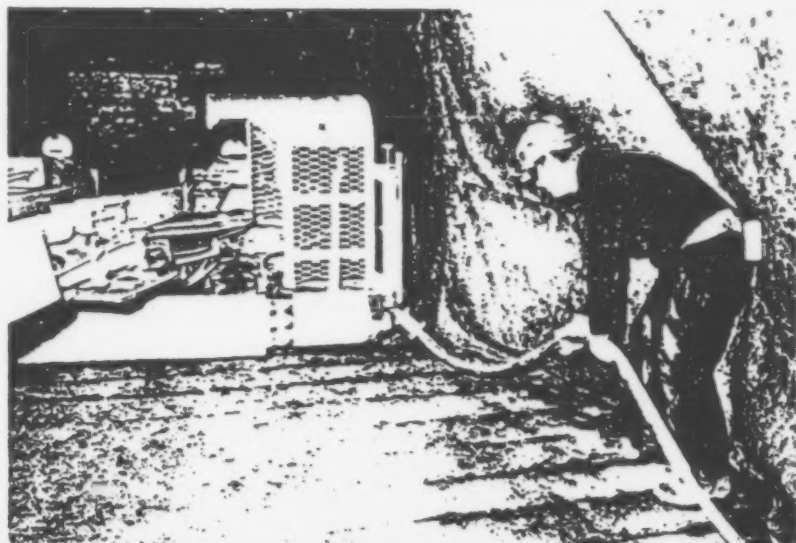


Prototype GFR's installed in underground load center

Coal Mine Trailing Cable Ampacity and Protection

Trailing cables are the electrical system components most frequently handled by mine personnel. Present Federal regulations limit their ampacities to values that may no longer meet the demand of increasingly powerful mining machines. At present, the only way to meet this demand is to increase cable size to accommodate larger currents. However, the need to reel or manually handle trailing cables places a practical limit on bulk and weight. An alternative that the Bureau and MSHA have been considering is to increase the amount of current rather than the cable size. This would

have several advantages, such as the use of smaller, lighter cables adapted to a specific duty cycle. However, this raises problems of coal dust ignition, risk of burns to personnel, and particularly as to the effect on cable life and safety of the increased heat generated by the higher current. The Bureau has been investigating this through accelerated aging laboratory tests where cable samples are heated for different times. These tests will continue in FY88, as will follow-up end-of-life tests. The results will be used to establish critical electrical and mechanical failure criteria, and to develop Arrhenius models of cable life vs. temperature. Intermittent and continuous loading tests of reeled and high-voltage shielded cables will be conducted. The temperature of low voltage cable components will be monitored with currents of short-circuit magnitude.

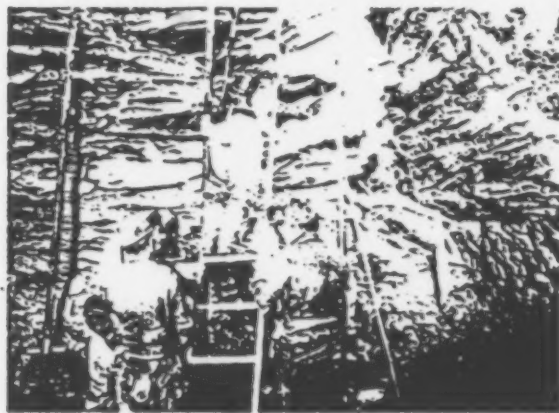


Miner handling portable power cable underground

MINE DISASTER PREVENTION

Unconfined Blasting: Sheathed Explosive Charges

Conventional blasting in underground coal mines makes use of explosive charges confined in suitably stemmed and primed boreholes. However, there are tasks, such as bringing down loose roof slabs or removing roof support cribs, which are not amenable to borehole blasting. In FY82, the Bureau developed a sheathed explosive charge capable of breaking stone slabs, about 3 ft² and 1 to 2 ft thick without igniting flammable mine atmospheres, thanks to a protective outer layer of

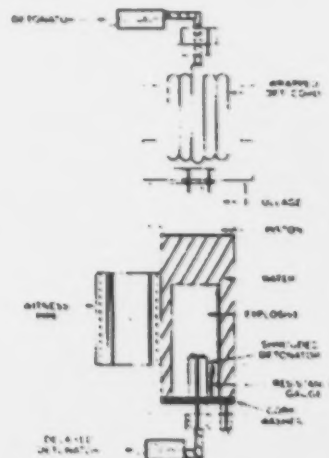


Preparing to bring down loose rock slabs using unconfined sheathed charges

damp salt. The prototype charge consisted of 1 and 1/2 lbs of permissible water gel, shaped into a short cylinder and encased in a 1/2 in layer of damp salt. However, before this charge concept can be commercialized, its safety in various applications must be established. The Bureau, in cooperation with MSHA, is preparing a test schedule for the approval of the unsheathed charge concept as permissible and suitable for commercial development. In FY88, the Bureau will evaluate new applications proposed by industry and advise MSHA as to their safety. Specialized charges will be developed for breaking coal mine ventilation seals; concrete block barricades will be the prime targets.

Detonation and Deflagration Criteria for In-Situ Mining Conditions

Failure (deflagration) of a borehole charge in a blasting pattern to detonate interrupts production, and creates an extremely hazardous condition. Explosives which fail to detonate in underground blasting are potential ignition sources in combustible atmospheres. Modern permissible explosives, such as water gels and emulsions, are particularly subject to deflagration, generally due to desensitization of the charge by the sudden dynamic pressure generated by the detonation of an adjacent charge. In the U.S., there are as yet no official tests to predict deflagration and dynamic desensitization, but Bureau research has resulted in two devices for measuring these effects -- the rupture disk fixture where the distance between the suspended igniter and the charge is the critical parameter, and the more recent nozzled pipe fixture, used to determine whether the explosive can detonate normally immediately after compression by a dynamic pulse from an adjacent charge. In FY88, research will continue into conditions causing malfunction and degraded performance of permissibles and delay detonators. A suitable test for evaluating deflagration tendencies will be developed based on pyrogenic initiation.



Test apparatus to simulate conditions in a borehole

Hazard Detection and Instrumentation

Rapid and reliable detection of a developing fire, transmittal of fire alarm warnings to all underground personnel, and identification of the safest evacuation paths are all critical factors in preventing mine disasters. A number of continuing and new Bureau projects are dealing with various aspects of these problems. Research on fire sensors and sensing systems makes use of the fact that fires are characterized by light, heat, and combustion products. In the case of incipient smoldering fires, the combustion products, more especially CO and smoke particles, have proved the most useful indicators. The Bureau's submicron particle detector (SMPD) gives the most

rapid response to incipient fires of any detector evaluated. In FY88, new developments in fire sensors will be evaluated, with emphasis on shaft fires and distinguishing between products of mine fires and diesel exhaust particulate. Development of a remote detecting methanometer will continue with evaluation of a fourth generation prototype; since this device measures the average methane concentration, a methodology will be developed that relates this average level to the potential explosion hazard of the mine atmosphere. New detection concepts to be explored include a gob fire/spontaneous combustion sensor, based upon residual CO levels, and fiber-optic based sensors for continuous in-mine monitoring of methane and other gases.



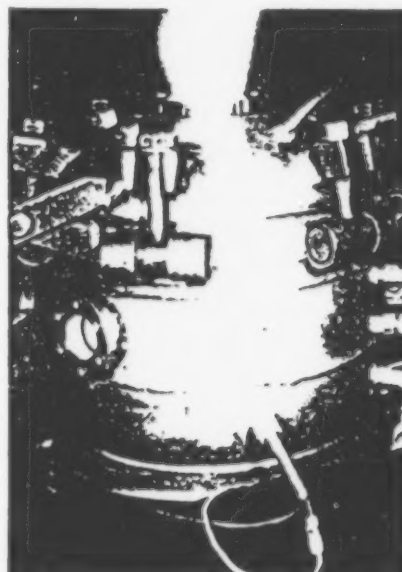
Using prototype remote methanometer to make measurements at coal face

MINE DISASTER PREVENTION

Testing and Evaluation of Explosion Hazards of Mineral and Industrial Dusts and Gases

Bureau research is seeking to provide the essential database required to assess the fire and explosion hazards created by the presence of flammable dusts and gases. A delineation of the physical domains of explosibility and ignitability for a substance or combination of substances is the essential safety engineering database required to develop meaningful safety standards and regulations. The results are used to evaluate existing regulations, standards and engineering practices, to recommend the adoption of new ones or the removal of unnecessary, ineffective or counterproductive ones. Laboratory studies in a series of Bureau-developed explosibility test chambers have clearly shown the relationship between flammability limits and thermal ignition probability for coals and other dusts in function of their concentration, rank, and particle size. Electric ignitability data have also been obtained. In FY88, initial screening experiments will be conducted in the 20-liter chamber with monodispersed dusts centrifugally classified to the finest sizes; mixtures of coal dust, inhibitor dusts and methane in air will be used to estimate particle diameter effects. A larger furnace will be constructed to determine minimum autoignition temperature measurements under more realistic conditions.

20-liter chamber used to study dust explosibility



Mine Fire Detection Strategies

Once a fire has been detected, successful evacuation depends on identification of the escape routes where air remains uncontaminated by fire products. This involves predicting air flow patterns using the Mine (Fire) Ventilation Code developed under a Bureau contract by Michigan Technological University. In FY88, the MTU Code will be used to determine optimum sensor locations and escape paths in a cooperating mine.

Fire detectors and alarm systems will be designed and displayed in such a way that the remotest personnel will be alerted and informed of safe escapeways. The resulting system will be tested, using simulated mine fires to evaluate its performance.



Computer display of mine-wide fire detection and monitoring system

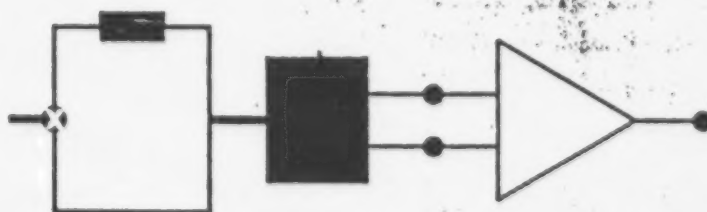
Diesel-Discriminating Mine Fire Sensors

In mines using diesel-powered equipment, early fire detection runs into a problem--distinguishing between diesel exhaust and the combustion products of an actual fire. A fire sensor designed to detect only concentration levels of a specific product (CO or smoke) cannot distinguish whether the source is diesel exhaust or a mine fire; significant false alarms can result. A rapid, reliable method is needed to detect a developing fire in the presence of diesel exhaust. Previous observation has shown that fire smoke particles, passed through a pyrolysis tube at 350 C, increase significantly in number. Diesel particles, on the other hand, remain unaffected by this treatment. By measuring repyrolyzed particle concentrations vs. unpyrolyzed concentrations, a mine fire can be detected even in the presence of diesel exhaust. In FY88, a novel dual ionization chamber will be used to sense the difference in signals of pyrolyzed and unpyrolyzed particles. Efforts will be made to increase the sensitivity and continuous operation of the chamber concept. The feasibility of applying pyrolysis to discriminate between diesel exhaust particles and respirable coal dust particles will be investigated further.

Thermochemical Pyrolysis and Microscopic Structure of Mineral Extinguishants and Explosive Dusts

Coal dust explosions and coal seam fires propagate by a thermochemical mechanism whose critical first step is the pyrolysis and devolatilization of coal. The reaction mechanism by which mineral-derived substances, such as rock dust and phosphate powder, extinguish explosions involves that same critical first step of pyrolysis and devolatilization. Studies of the basic thermochemical mechanism of pyrolysis and devolatilization are therefore fundamental to an understanding of how dust flames propagate and how they are extinguished by powdered inhibitors. They also relate to efficient coal utilization in power plants and to the production of synthetic fuels.

Another factor is the microscopic structure of dust explosion residues as determined by a scanning electron microscope (SEM). The residues are compared with char residues from laser pyrolysis experiments and dust samples from real mine disasters. Current research is improving and expanding the pyrolysis of ultrafine particles. In FY88, laser pyrolysis and SEM studies will be



Schematic of diesel-discriminating fire sensor based on smoke analysis. Repyrolysis causes smoke particles to multiply; diesel particles remain virtually unchanged

MINE DISASTER PREVENTION

extended to metal dusts. Knowledge acquired in previous years will be used to develop superior mineral-based extinguishants as supplements for rock dust. SEM morphological studies will be extended to postdisaster investigations.



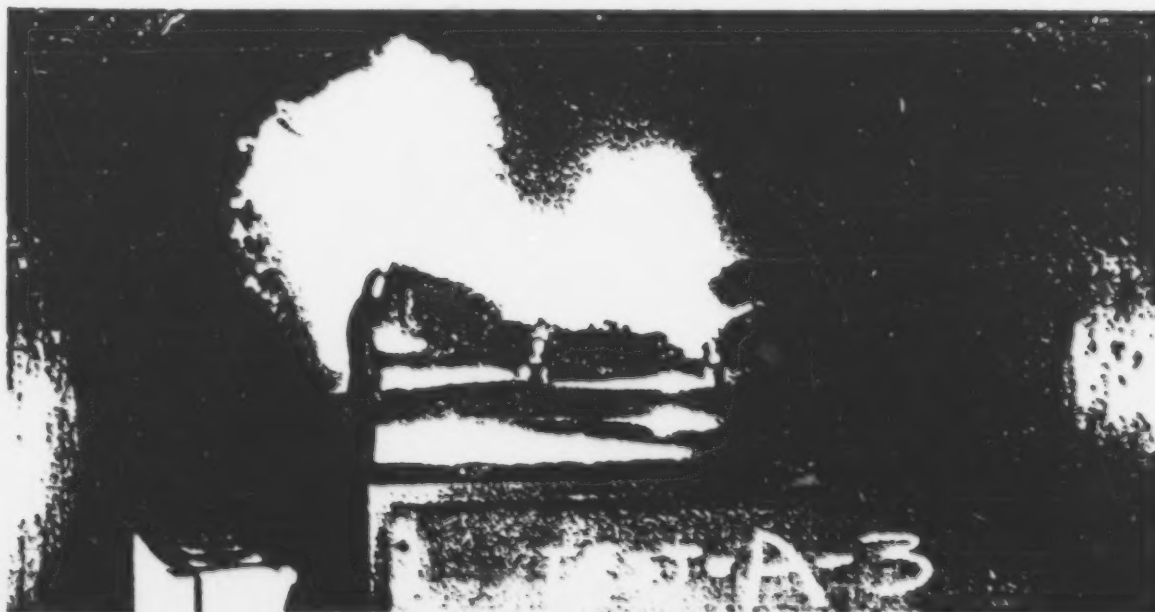
Studying coal particle pyrolysis with a laser beam

Fire Hazards of Mine Combustibles

Fire hazards exist in underground coal mines not only due to the mine atmosphere, but

also due to the materials introduced into the mine, such as wood timbering, conveyor belting, sealants, lubricants, ventilation ducts and brattice cloth. The objective of this project is to determine the flammability hazards of these materials, so as to allow the industry to select the most flame-resistant products. Full-scale and laboratory tests are developed and applied for this purpose. In FY88, full-scale tests at the Lake Lynn surface gallery will continue to evaluate the flammability of rubber and PVC conveyor belts, as a function of fire damage, flame spread rate, downstream air temperature and combustion gas concentrations (O_2 , CO , CO_2). Emphasis will be on the effect of ventilation airflows, ranging from 150 to 800 ft per min. The ignition source is a slowly developing coal fire, ignited by a simulated hot roller. Samples of the same belts will undergo various laboratory-scale tests and the results will be compared with the full-scale test results. If fire resistance ranking is the same, plans are to develop a reliable laboratory-scale test that would be less expensive and time consuming than the full-scale test.

Trials to determine effect of ventilation on conveyor belt burning velocity



Full-Scale Mine Explosion and Suppression Research

Past research on the control of coal mine explosions has approached the problem in two ways: (1) preventing the formation of combustible coal dust-air mixtures by the addition of adequate amounts of inert dust and (2) arresting the explosion by means of passive and triggered barriers. This research has generally been conducted in relatively small single entries. Information is lacking on explosion propagation in multiple-entry mines, especially U.S. coal mines where room-and-pillar techniques offer many possible propagation paths. The general approach is to define the conditions in which various combinations of coal dust, methane and inhibitors could constitute a hazard, and identify the chemical and physical phenomena associated with the propagation of a full-scale explosion. To provide such information, the Bureau has undertaken the study of the mecha-

nisms of explosion initiation, propagation and suppression in single and multiple entries. In FY88, flame velocities, dynamic pressures and other explosion parameters will be measured as functions of stopping strength, rock dust concentration, dust distribution and ignitor strength. A mine explosion model will be developed and verified against experimental results. Passive and triggered barriers will be tested in the full-scale room-and-pillar configuration at Lake Lynn.

Explosion of predispersed coal dust at Bruceton Experimental Mine



MINE DISASTER PREVENTION

Preventing Frictional Ignition

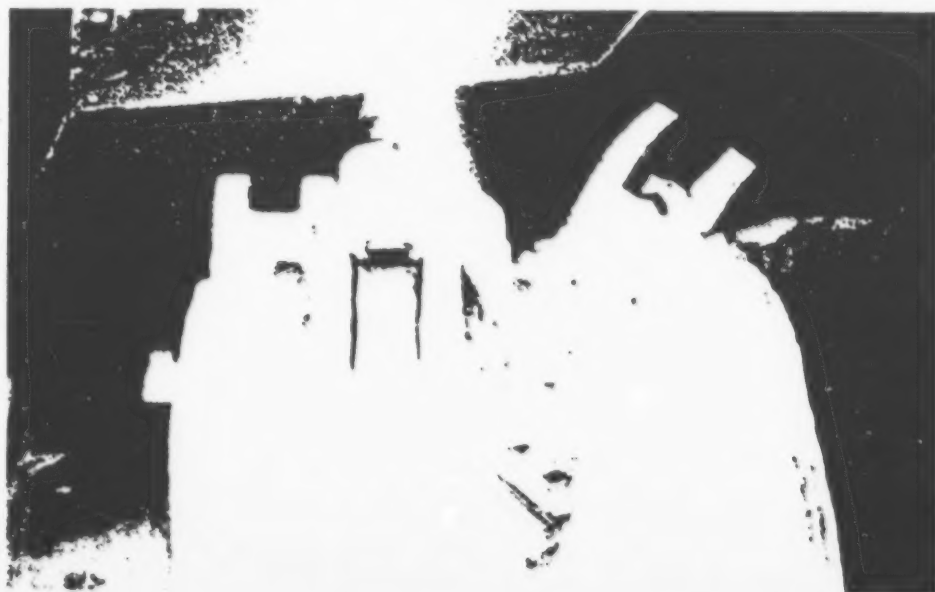
Frictional ignition has long been a serious problem in U.S. coal mines. It is usually caused by a hot streak formed when the cutting tool of the mining machine cuts into a sandstone inclusion in the coal face. This hot streak ignites a nearby combustible mixture of methane/air, leading to a fireball. Although this fireball is usually only a few feet in diameter, it can ignite a full-scale dust explosion. In the past several years, some 75 incidents of frictional ignition have been reported annually. Research by the Bureau, early in the 1970's, produced an "anti-ignition" bit in which a mushroom-shaped tungsten carbide tip protects the steel shank, determined to be the main cause of ignition; by increasing the attack angle, the number of bits could be decreased and the production rate increased. Research with the new bit demonstrated that the probability of ignition increased dramatically when the bit became worn and the steel shank became exposed. Ignition was essentially eliminated, even with a worn bit when a carefully designed and oriented water spray nozzle was mounted behind the bit; this also reduced respirable dust. In FY88, field trials will continue to generate information on bit life, fric-

tional ignition statistics and increased productivity. Laboratory studies will evaluate other bit and shank materials and develop a better understanding of mechanisms of frictional ignition. Work will continue to transfer "anti-ignition" bit and water spray technology to the industry.

Fire and Explosion Hazards of Noncoal Mining

An extensive technology on the prevention and control of mine fires is available from the Bureau's research on coal mine safety. Much of this information has been applied in initial pilot plant laboratory and field studies on the explosibility of oil shale dust. However, much remains to be done to develop necessary safety criteria, particularly with respect to blasting and gas emissions in oil shale, oil mines, sulfide mines, salt mines and other noncoal mines. In oil shale blasting operations, for example, secondary explosions could be initiated, involving methane and/or oil shale dust generated during the fragmentation process. These secondary explosions could initiate propagating dust explosions in the main entries. Bureau research involves three tasks: (1) large-scale explosion and fire research at

Machine-mounted water sprays prevent frictional ignitions at coal face



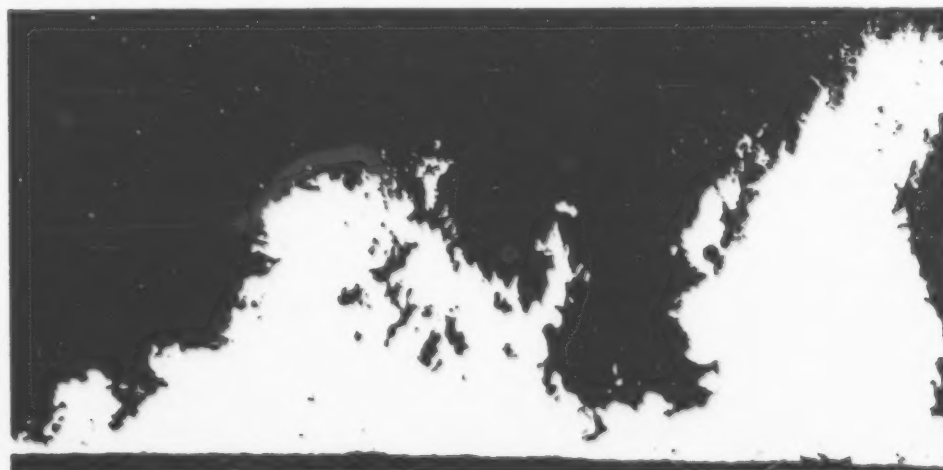
Bruceton and Lake Lynn; (2) evaluation of transport and deposition of dust particles ejected by a blast as well as transport and dilution of any methane that may have been emitted; and (3) identification of coal mining technology applicable to the oil shale industry, in spite of important differences in mining practices and techniques. In FY88, it is anticipated that the two major efforts will center around hazards of dust from oil shale blasting and of methane released during blasting and processing. A mine explosion model will be developed and compared with experimental results.



Extinguishing an oil shale fire with foam

Mine Fire Diagnostics, Control and Extinguishment

Mine operators confronted with a catastrophic fire must have strategies for fighting it, and if necessary, sealing it; criteria for reopening a sealed fire are also essential. Premature reopening can result in reignition; unnecessarily prolonged sealing can be economically damaging. The strategy and techniques for fighting mine fires are extremely important, both for lifesaving and for productivity. For a fire burning out of control, the ability to reach and use escapeways depends on the availability of uncontaminated air; stoppings play a crucial role in controlling the ventilation flow. Research in FY88 will use three approaches: (1) diagnostics will be developed for reopening sealed mines, based on the controlled burning of a standardized 15-ton coal pile sealed and treated by surface injection of carbon dioxide; (2) evaluation of the status of sealed fires based on analysis of residual gases and submicrometer particulate; and (3) evaluation of the relative effectiveness of concrete block and galvanized steel stoppings in preventing the spread of a mine fire and toxic combustion products.

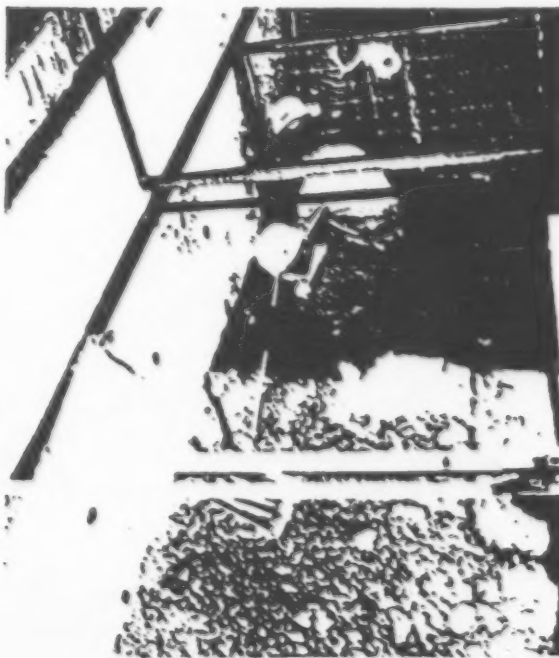


Liquid fuel fire used in full-scale fire endurance tests of mine stoppings

MINE DISASTER PREVENTION

Spontaneous Combustion Research

Approximately 11 pct of underground coal mine fires in the United States are caused by the spontaneous combustion of coal. This number is expected to increase with greater coal consumption and utilization of lower rank coals, deeper mines, and the expansion of longwall mining. The self-heating of coal in mines usually occurs in a worked-out or gob area and is not easily detected. The resulting fire presents a serious safety hazard and often requires sealing large sections of the mine or the entire mine for long periods. Self-heating of oil shale could also be a potential safety hazard in underground oil shale mines. Large shale piles are created in mines by blasting operations, and the mines would like to use raw oil shale to construct large stoppings. A thorough investigation of the spontaneous combustion characteristics of oil shales is required to assess the risk of spontaneous combustion fires in oil shale mines.



Inserting temperature probes into 15-ton coal bed to study self-heating hazards

For several years, the Bureau has been conducting experiments on the self-heating of coal and oil shale in small-scale and large-scale test systems. These will continue in FY88. Laboratory-scale test procedures include an adiabatic heating apparatus, a modified autoignition temperature furnace, and a closed vessel desorption apparatus. However, in actual self-heating events in coal mines, much larger coal masses are involved. To adequately simulate such conditions, a large-scale test apparatus has been constructed which simulates a gob area. In FY88, tests on different scales will continue to provide information on the self-heating tendencies of various coals and oil shales. A newly constructed large-scale installation that simulates a gob area will contribute spontaneous combustion information under realistic conditions, including control and prevention methods, such as sealing, and quenching additives.

Fires in Mine Passageways

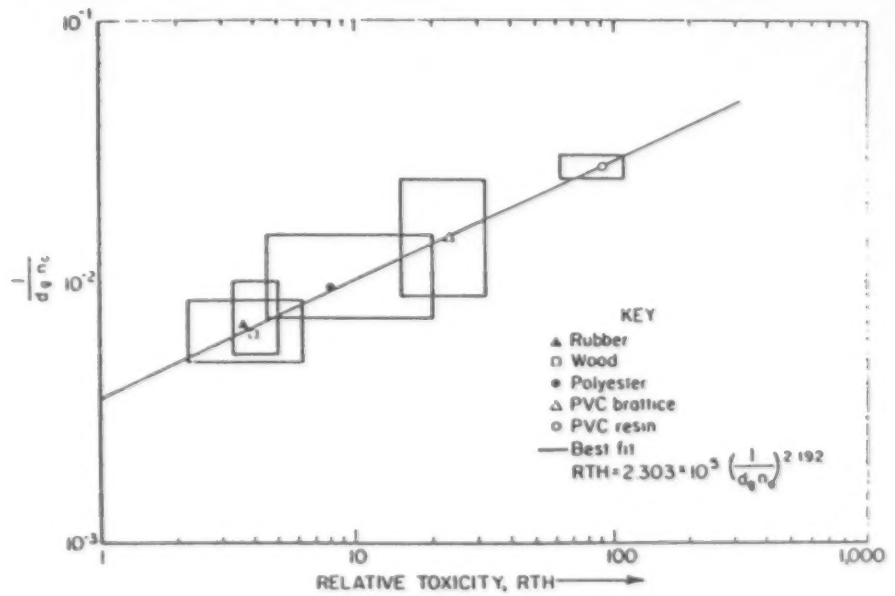
Fires can propagate rapidly throughout a mine, carrying lethal levels of toxic gases and smoke into work areas and escape routes. Many factors combine to promote flame growth and spread accompanied by heat, toxicity and poor visibility. The rate of fire growth is influenced by the mode and intensity of ignition, but quantitative data are lacking. The rate of fire growth depends also on the type of combustibles and their distribution within an entry; differences have been found, but not quantified, for coal and wood. Bureau research is attempting to distinguish and quantify their interaction by way of laboratory-scale, intermediate-scale and full-scale tests. These tests have been used to verify models that define conditions necessary for ignition and propagation of mine fires. In FY88, a correlation will be sought between the smoke particle diameter and concentration product ($d_p n$) and the toxic load for brattice cloth and conveyor belts which contain significant amounts of chlorine. Generation rates of CO , CO_2

and smoke will be determined for brattice materials and ventilation ducts. An in-depth study of flame spread across horizontal solid fuels (flat wood sheets) will be initiated and theoretical models to predict flame spread for such configurations will be evaluated.

Ventilation to Minimize Underground Fire Hazards

In case of a fire in an underground coal mine, the mine ventilation networks provide excellent paths along which fire can propagate and toxic gases can travel to the working face; in underground metal/nonmetal mines, multiple fan-in-duct series ventilation systems are subject to leakage, recirculation and degradation of the air quality reaching the face. The Wilberg Mine fire in 1984 is a tragic example of the catastrophe that can ensue. The purpose of this Bureau research is to provide the industry with ventilation systems that are fail-safe and prevent combustion products from being entrained by the main ventilation air. Areas of special concern are ventilation of haulageways, use of ventilation controls in mine fires, and ventilation of power center transformers. Much information is needed on the multiple fan-in-duct series ventilation of metal/nonmetal mines; this includes placement, airflow, fan capacity, duct sizing and type, recirculation, etc.

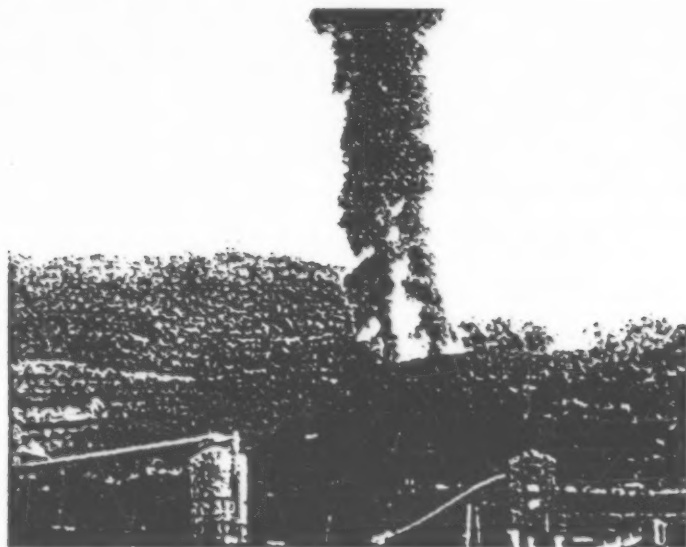
Correlation between relative toxicity and smoke parameter, $1/d_n$.



Research in FY88 will develop a preliminary fault tree analysis of coal mine escapeways. Belt entry ventilation will be studied as it relates to the intake escapeway in case of fire. The effectiveness of seals will be evaluated in an actual mine fire. This would require addition of gas monitors and ventilation doors that automatically change the airflow patterns in case of fire, but it would avoid the need to sink an additional ventilation shaft. The feasibility of recirculating air from an underground repair shop at a trona mine will also be assessed.

MINE DISASTER PREVENTION

Products of combustion from a mine with an underground fire

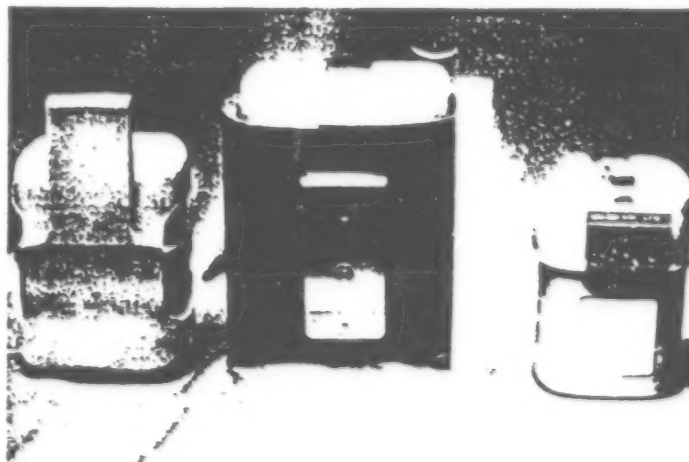


Life Support for Escape and Rescue

Federal regulations require anyone who goes into an underground mine to be equipped with a self-contained self-rescuer (SCSR) capable of supplying the wearer with a respirable atmosphere (oxygen) for 1 hr. Currently all 1 hr SCSR's approved officially for use underground are bulkier and heavier than the standard filter self-rescuer (FSR) which can be carried on the miner's belt, but only protects against low levels of carbon monoxide and provides no oxygen to the wearer. Because of its size and weight, it is customary to carry the present 1 hr SCSR into the mine and store it close to where the miner is working. The present need is for an emergency breathing apparatus about twice the size and weight of an FSR that could be belt-worn and would supply the wearer with needed oxygen. Federal regulations also require rescue teams to be equipped with self-contained breathing apparatus

(RBA's) that have at least 2 hrs of service. Such apparatus are commercially available. However, based on the most recent technology, a smaller, lighter RBA designed for low coal mine rescue and recovery missions, has become possible. This device could be integrated with a rescue team helmet (RTH), that would provide head and eye protection, communication, and illumination in conjunction with life support functions. Previous Bureau research has produced such a prototype apparatus (LP120/RTH) which will be field tested on a limited scale in FY88; a performance comparison of RBA's available world-wide will be conducted to aid mine operators and manufacturers in the selection and design of RBA's most suited to their

specific purposes. Physical stressor limits, previously determined, will be considered in revising certain regulations, and a quantitative, repeatable leak test will become available for closed-circuit breathing apparatus.

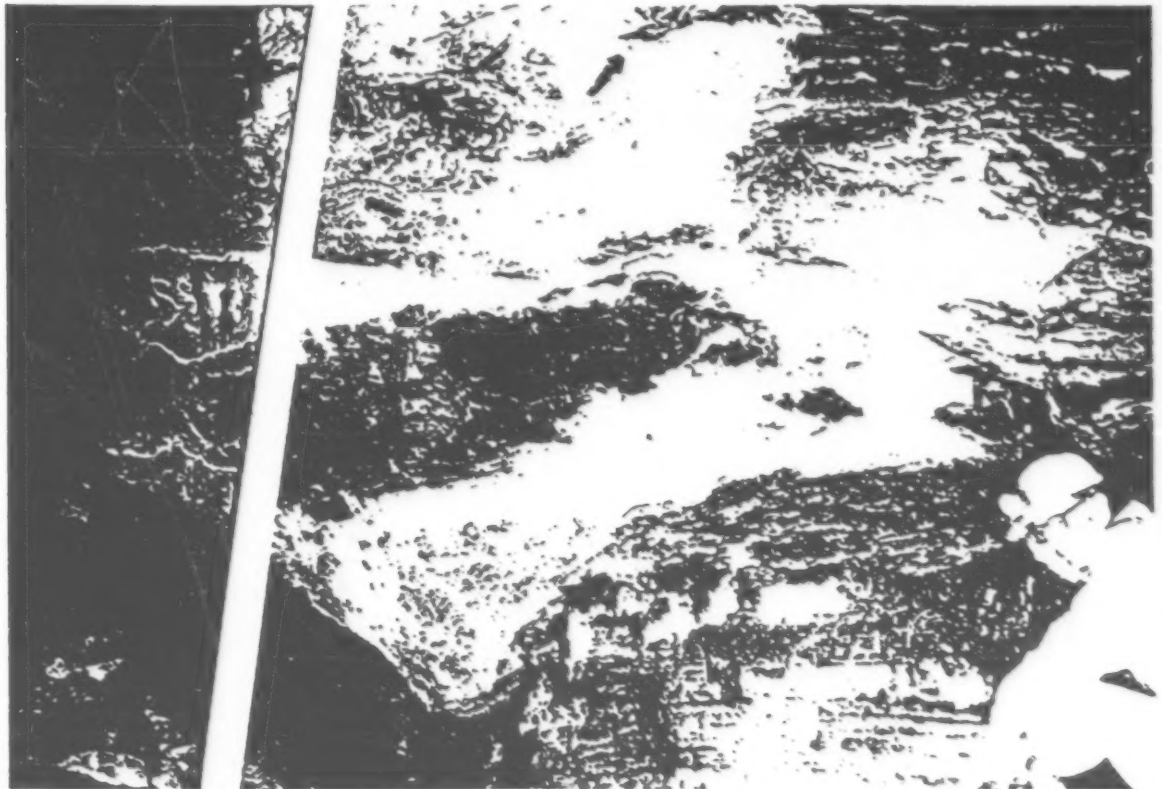


Belt wearable self-rescuer compared with filter self-rescuers

Influence of Mine Design on Methane Emissions

Methane gas is an inevitable by-product of coalification and the primary source of coal mine fires and explosions. Hazardous accumulations of methane have been successfully controlled in two ways: (1) ventilation to dilute the methane released by mining and (2) drainage of gas occluded in the seam in advance of mining. However, as coal mines go deeper and mine designs change, these conventional methods may no longer be adequate. Abandoned mine sections increase as more coal is mined. Current methods of sealing or ventilating both have drawbacks. Bureau research is investigating the effect of changing mine designs on methane emissions. Future longwall panels will double in size; gob areas will

grow; development entries driven 10,000 ft into virgin coal will result in unprecedented methane emissions. Simultaneous mining of multiple seams can also lead to unpredictable methane emissions. Transferring previous solutions into the new mine scenarios is a major task which the Bureau is seeking to resolve through the application of artificial intelligence and the development of expert systems. In FY88, work will continue to collect methane emission data at two mines working multi-size longwall panels and to prepare a methane migration model for predicting gas emissions during various mining scenarios in the Pocahontas No. 3 coalbed; gas emission will be correlated with longwall dimensions and time intervals. An expert system for methane control (MethPro) will be completed and evaluated.



Clastic dike cutting through a longwall panel in an underground coal mine

CHERCHAR - FRANCE

EXPERIMENTAL FIRE GALLERY

Verneuil-en-Hallette

Galerie expérimentale d'incendie

Dans le domaine de la sécurité, le CERCHAR s'est toujours préoccupé des problèmes d'incendie et d'explosion. Déjà équipé en laboratoires d'essais et d'analyses, le CERCHAR s'est doté d'un outil unique, une galerie expérimentale d'incendie particulièrement adaptée pour :

- les études d'incendie en milieu confiné et ventilé,
- les essais mettant en œuvre des produits dont la combustion dégage des substances polluantes ou toxiques.



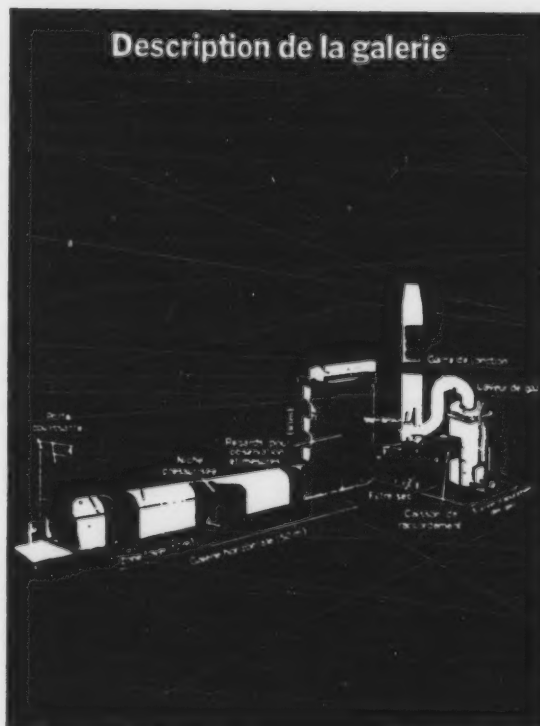
- Une partie horizontale :
 - longueur 50 m,
 - largeur effective 3 m,
 - hauteur des murs 2 m et une voûte en demi-cercle de 1,5 m de rayon,
 - section 10 m².

Les parois sont en béton réfractaire et isolant conçues pour supporter des températures supérieures à 1 200°C et des chocs thermiques violents.

Les dimensions sont suffisamment importantes pour permettre d'étudier le comportement au feu de gros équipements tels que des transformateurs électriques ou engins sur roues ; le sol en béton réfractaire est également prévu pour supporter de telles charges.

La niche ménagée au milieu de la partie horizontale, est destinée à essayer les équipements de protection contre les gaz toxiques générés par un feu situé en amont.

Description de la galerie



- Une partie verticale :
 - section rectangulaire (3 m x 2 m),
 - hauteur 10 m.

Elle est garnie de béton réfractaire. Elle permet tant d'étudier la propagation verticale d'incendie que d'évaluer les quantités de substances toxiques et la chaleur émise par un feu situé dans la partie horizontale. Les gaz sont ramenés au niveau de la station de dépollution par une conduite descendante de 1,80 m de diamètre.

Une station d'épuration des fumées constituée de :

- un système de refroidissement par pulvérisation d'eau installé dans la conduite circulaire descendante,
- une entrée d'air réglable pour la dilution des gaz de combustion et la limitation de la température,
- un filtre sec où sont retenus les aérosols, la suie et les poussières,
- un laveur multicellulaire à contre-courant,
- un ventilateur extracteur à vitesse ajustable,
- une cheminée de 18 m.

Toutes les eaux polluées sont recueillies et traitées avant rejet dans l'environnement.

Comportement des matériaux polymériques dans un incendie en galerie de mine

.par

J. DANGREUX, M. KAZMIERCZAK et R. CHAUVIN

Comportement des matériaux polymériques dans un incendie en galerie de mine

1. INTRODUCTION

La mine moderne fait appel de plus en plus aux matériaux polymériques pour de multiples utilisations qui vont des bandes transporteuses aux résines expansibles en passant par les isolants des câbles électriques, les ventubes et les films plastiques. Les engins en service dans les travaux souterrains utilisent également des polymères, ne serait-ce que pour les pneus.

Ces matériaux polymériques peuvent représenter un potentiel calorifique important et il est nécessaire d'examiner les problèmes que leur utilisation pose vis-à-vis de l'incendie dans un milieu confiné comme celui de la mine. Leur combustion peut augmenter la puissance de l'incendie et favoriser sa propagation. Les produits gazeux de réaction peuvent être inflammables et donner lieu au phénomène d'embrasement généralisé. Ils peuvent être toxiques et avoir des conséquences sérieuses sur l'atmosphère des chantiers souterrains. Enfin, la plupart de ces matériaux en brûlant dégagent des fumées opaques qui peuvent rendre difficile l'évacuation des mineurs.

Dans les grands pays miniers, les matériaux polymériques avant de pouvoir être utilisés au fond doivent satisfaire en général à un certain nombre d'essais destinés à caractériser leur comportement au feu. Les tests ont pour objectif essentiel d'évaluer le risque de propagation du feu mais très peu s'intéressent aux conséquences que peuvent avoir les dégagements de produits de décomposition thermique de ces polymères sur l'atmosphère de la mine. La nature des produits de pyrolyse va dépendre de la part relative des phénomènes de décomposition thermique et des phénomènes de combustion dans l'incendie où se trouvent impliqués des matériaux polymériques. Leurs conditions de mise en œuvre dans les chantiers souterrains auront donc une influence importante. Leur comportement sera également différent selon qu'ils se trouvent dans le brasier ou sont soumis aux fumées chaudes à une certaine distance de l'incendie.

En conséquence, pour mieux apprécier les risques vis-à-vis de l'incendie que présente l'utilisation des matériaux polymériques au fond, le Cerchar a construit une galerie pour étudier à l'échelle réelle leur réaction au feu dans les conditions de leur emploi dans les chantiers souterrains.

* Centre d'Études et Recherches de Charbonnages de France.

Ce sont les résultats obtenus sur quelques bandes transporteuses en polymères halogénés et sur une mousse urée-formol qui sont exposés ci-après.

2. DESCRIPTION DE LA GALERIE (fig. 1)

Commencée en 1982, la galerie incendie a été mise en service en 1983.

Sa conception a été guidée par les impératifs suivants:

- possibilité de réaliser les scénarios d'incendie susceptibles d'être rencontrés au fond, avec propagation du feu horizontalement ou verticalement, à co- ou à contre-courant de l'aérage;
- obtention de transferts thermiques entre les fumées et les parois comparables à ceux qui existent dans une galerie de mine;
- dépollution des fumées avant leur rejet à l'atmosphère pour autoriser l'implantation de la galerie dans l'enceinte même des Laboratoires du Cerchar, à Verneuil-en-Halatte, et bénéficier ainsi de tout le potentiel scientifique et technique voulu.

La galerie incendie est constituée par une partie horizontale de 10 m² de section et longue d'une cinquantaine de mètres, suivie d'une partie verticale de 6 m² de section et d'une dizaine de mètres de hauteur. Une vue isométrique de l'installation est donnée figure 1. La portion horizontale a une largeur utile de 3 m, une hauteur de pied-droit de 2 m, la voûte étant un arc en plein cintre de 1,5 m de rayon. La partie verticale a une section rectangulaire de 3 x 2 m. Ces dimensions permettent d'introduire dans la galerie horizontale un engin sur pneus et étudier son comportement dans un incendie par exemple.

La galerie est constituée par un assemblage de viroles en acier garnies intérieurement d'un revêtement en béton réfractaire isolant conçu pour supporter des températures de 1 200 °C et résister à des chocs thermiques violents. Le plancher également en béton réfractaire a la résistance mécanique nécessaire pour supporter de lourdes charges comme le poids de véhicules (camions, chargeurs, etc.) dont l'empattement ne dépasse pas 3 m. À mi-longueur de la galerie horizontale, a été aménagée une niche pour pouvoir étudier les problèmes relatifs aux niches pressurisées dans lesquel-

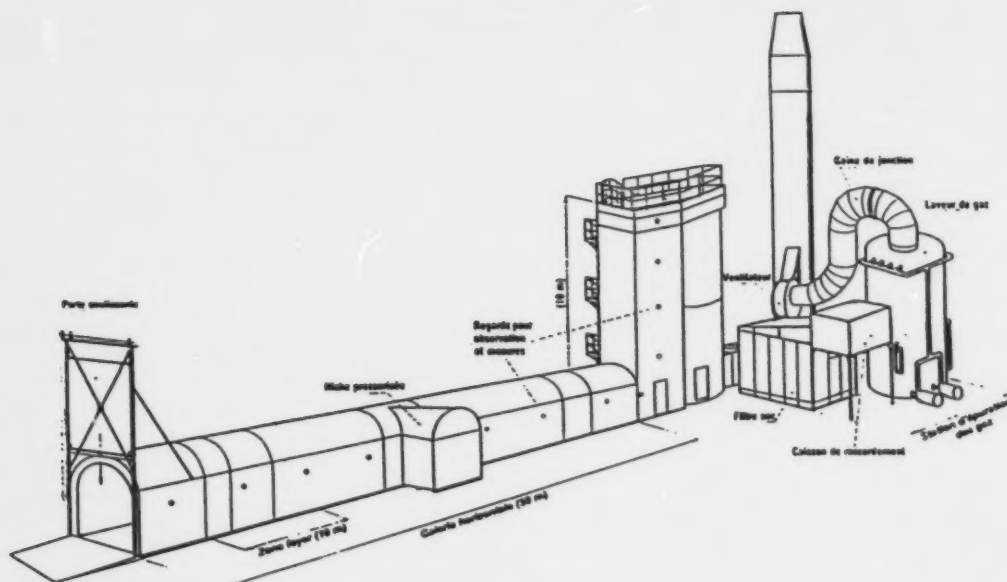


Fig. 1. — Galerie d'incendie (Cerchar).

les peuvent trouver refuge les mineurs en cas d'incendie. La portion verticale de la galerie est conçue pour pouvoir étudier les feux de nappes de câbles électriques.

Avec comme point fixe la partie verticale de la galerie, la portion horizontale repose sur des rails pour permettre le libre jeu des dilatations.

Au point de vue de l'aérage, la galerie fonctionne en dépression pour réduire au minimum les risques de fuite vers l'extérieur des produits nocifs issus de l'incendie de certains polymères. Les fumées à leur sortie de la galerie verticale sont ramenées au niveau du sol par un cameau vertical en tôle de 1,8 m de diamètre. En tête de cameau, il est possible de pulvériser finement de l'eau pour refroidir les fumées et/ou condenser les vapeurs de composés organiques. Les gaz entrent ensuite dans un filtre sec destiné à arrêter les aérosols, les suies et les poussières puis dans un laveur à gaz où sont retenus les composés acides tels que l'acide chlorhydrique, l'acide cyanhydrique... A leur sortie de cette station de dépollution, les fumées sont aspirées par le ventilateur de circulation avant d'être rejetées à l'atmosphère par une cheminée. Les eaux provenant de la pulvérisation en tête de cameau et du laveur sont traitées avant d'être rejetées de manière à éviter tout risque de pollution.

Différents organes de réglage existent pour réaliser un débit d'air et une dépression donnés dans la galerie incendie. A l'entrée de celle-ci une porte guillotine permet de faire varier l'ouverture équivalente. A l'entrée du filtre sec, un registre à ventelles motorisé permet de réduire le passage des fumées; il est suivi d'une entrée d'air réglable pour refroidir si nécessaire les gaz avant leur entrée en contact avec les médias filtrants. Enfin, un coupe-tirage est placé avant le ventilateur dont la vitesse est fixe, mais peut être changée à l'arrêt en modifiant le rapport des poulies.

Le débit d'air maximal est de $54\,000\text{ m}^3/\text{h}^{**}$, soit une vitesse d'aérage de l'ordre de 1,5 m/s dans la galerie horizontale. Toutefois, l'utilisation du laveur à gaz limite le débit

à $30\,000\text{ m}^3/\text{h}$ pour des raisons de primage excessif de la solution alcaline au-delà de cette valeur.

Au point de vue thermique, il a été nécessaire de trouver un compromis entre les impératifs d'isolation calorifique et de résistance au choc thermique du béton réfractaire à utiliser pour le revêtement interne des parois de la galerie et les propriétés de transfert de la chaleur dans les terrains dans les travaux souterrains. Une fois déterminées les caractéristiques du béton réfractaire à employer, un garnissage composite a été en réalité nécessaire; son épaisseur a été déterminée pour que soient réalisées pendant environ 90 min les mêmes conditions de transfert de chaleur que dans un massif semi-infini. Cette épaisseur est de 0,25 m et le béton a été mis en place par coffrage sur les pieds-droits et par projection sur la voûte.

3. MATÉRIAUX POLYMÉRIQUES EXAMINÉS

La cause la plus fréquente d'incendie au fond de la mine est l'échauffement et l'inflammation des bandes transporteuses. Des exemples récents sont venus rappeler malheureusement que les conséquences de ces incendies pouvaient être fort graves sur le plan des pertes tant en vies humaines qu'économiques.

Parmi les autres matériaux polymériques qui sont utilisés en quantité importante dans les travaux souterrains, les mousses expansibles occupent une place grandissante et sont utilisées en injection pour la consolidation des terrains, l'étanchéement, la réalisation de barrages rapides, le garnissage des voies...

Il était par conséquent logique de commencer le programme de recherche sur le comportement dans un incendie au fond de la mine des matériaux polymériques par les bandes transporteuses et les mousses expansibles, programme mené avec l'aide financière de la Communauté européenne du Charbon et de l'Acier. Les premiers essais ont porté sur trois

** Dans les conditions normales de pression et température.

bandes transporteuses à carcasse textile, une en PVC et deux en chloroprène, et une en mousse expansible urée-formol.

Les caractéristiques des bandes transporteuses sont données dans le tableau I.

TABLEAU I

Revêtement	Chloroprène		PVC
Type (N. mm ⁻¹)	500	800	1250
Nombre de plis	monopli	deux plis	monopli
Largeur (mm)	800	1000	1000
Carcasse	textile	textile	textile
• Chaîne	polyester-coton	polyester-rayonne	polyester
• Trame	polyamide-coton	polyamide-rayonne	polyamide-coton
Épaisseur du revêtement (mm)	2 + 2	4 + 4	3 + 4
Classement en catégorie*	B	C	C
Analyse élémentaire**			
Carbone (%)	54,5	58,4	48,1
Hydrogène (%)	5,8	4,3	5,5
Azote (%)	2,6	0,3	1,0
Soufre (%)	0,7	0,6	0,4
Chlore (%)	21,8	18,4	24,6
Fluor (%)	0,02	0,01	0,01
Cendres (à 825 °C) (%)	0,1	12,6	4,8

* Décret n° 73-404 du 26 mars 1973, article 9.

** Analyse portant sur la bande entière (revêtement + carcasse).

La mousse urée-formol examinée a été mise en œuvre en garnissage de parois. Sa composition élémentaire après expansion et séchage est la suivante:

- carbone (%): 30,2;
- hydrogène (%): 5,9;
- oxygène (%): 21,5;
- azote (%): 29,4;
- soufre (%): 0,1;
- résidu à 820 °C: 1,6.

4. PROTOCOLE DES ESSAIS

Le scénario retenu pour les essais en galerie était celui d'un incendie relativement violent représenté par un bûcher de 300 kg de bois de peuplier séché auquel étaient soumis directement les matériaux polymériques examinés.

Le bûcher de bois a les dimensions suivantes: largeur = 1 m, longueur = 2,3 m, hauteur = 1 m; le centre du parallélépipède ainsi formé est à 9 m de l'entrée de la galerie. L'allumage du bûcher est réalisé à l'aide de 2 l de fuel lui-même enflammé avec 0,5 l d'alcool à brûler.

4.1. Cas des bandes transporteuses

L'échantillon de bande d'une longueur de 15 m est disposé dans l'axe de la galerie horizontale, parallèlement au sol et à 0,5 m de celui-ci. L'extrémité de la bande côté entrée de la galerie est prise en sandwich dans le bûcher sur une longueur de 2,3 m.

Des thermocouples de type K avec gaine inox de 1 mm de diamètre sont disposés à intervalles réguliers sur et dans la bande pour suivre la progression du feu. D'autres thermocouples sont placés dans les gaz à différentes distances de

la bande pour enregistrer la température des fumées. Enfin des fluxmètres sont disposés de manière à mesurer les flux thermiques émis par le bûcher et l'éclairage énergétique sur la bande transporteuse à différentes distances du brasier.

Des sondes de prélèvement de gaz sont disposées au voisinage immédiat de la bande et à 0,5 m au-dessus d'elle et sont reliées à des analyseurs de CO₂ et CO par infrarouge et O₂ par paramagnétisme. Des prélèvements en ampoules en verre permettent de doser dans les gaz l'acide chlorhydrique et les hydrocarbures aliphatiques et aromatiques.

En un point de la galerie situé à la partie supérieure de la portion verticale et où les gaz sont mélangés, sont effectuées des mesures globales de température et de composition de gaz pour déterminer les bilans thermique et massique de l'incendie. L'opacité des fumées quant à elle est mesurée à l'aide d'opacimètres selon les axes horizontal et vertical à une quarantaine de mètres du bûcher.

4.2. Cas des mousses

Le cas considéré est celui d'un garnissage de parois à l'aide d'une mousse urée-formol. Celle-ci est mise en place par projection sur un grillage fixé sur les parois de la galerie. L'épaisseur moyenne de la couche est d'environ 5 cm et le poids moyen au mètre carré est de l'ordre de 2,3 kg.

Le bûcher de 300 kg de bois est disposé de manière à être engagé entièrement dans la partie garnie de mousse de la galerie. Ses dimensions sont les mêmes que pour le cas des bandes transporteuses et son allumage est opéré de la même manière.

Des mesures de température à l'aide de thermocouples de type K avec gaine inox de 1 mm de diamètre sont effectuées dans l'épaisseur de la mousse à intervalles réguliers au voisinage de la clé de voûte d'une part, et dans les gaz à différentes hauteurs et distances du bûcher d'autre part. Des fluxmètres sont disposés pour enregistrer les flux thermiques émis par le bûcher et reçus par le garnissage de mousse à différentes distances du brasier.

Des sondes de prélèvement de gaz sont disposées en aval aéraie à 4 m du centre du bûcher, à la surface de la mousse et à proximité de la clé de voûte ainsi qu'à mi-hauteur dans la galerie. Elles sont reliées à des analyseurs de CO₂ et CO à infrarouge et O₂ par paramagnétisme ainsi qu'à des ampoules en verre pour des dosages par chromatographie et spectrométrie de masse.

Les mesures globales de température et de composition des gaz sont effectuées au point de mélange de la galerie pour déterminer les bilans thermique et massique de l'incendie. L'analyse continue de l'acide cyanhydrique et des oxydes d'azote est faite également à cet endroit ainsi que des prélèvements en discontinu pour déterminer les teneurs en suies, goudrons..., des fumées.

Des opacimètres permettent enfin de déterminer la densité optique des fumées.

5. RÉSULTATS OBTENUS

5.1. Bandes transporteuses

Les essais ont été effectués avec une vitesse d'air de 0,85 m/s et un bûcher de 300 kg de bois.

Les principaux résultats sont donnés dans le tableau II ci-après:

TABLEAU II

Bande transporteuse	Chloroprène 500	Chloroprène 800	PVC 1 250
Longueur totale détruite (y compris les 2,3 m engagés dans le bûcher) (m).....	15	6,4	2,3
Longueur portant des signes de dégradation thermique (m)...	(tout a brûlé)	0,8	0,2
Composition moyenne des fumées (au niveau du point de mélange)			
• CO ₂ (%).....	1,5	0,75	2,3
• CO (%).....	0,13	0,06	0,18
• O ₂ (%).....	18,9	20,2	17,8
• HCl (ppm).....	—	70	13

Dans les conditions d'incendie adoptées, on voit que la bande en chloroprène 500 brûle entièrement alors que celle en PVC 1 250 ne propage pratiquement pas le feu. La bande en chloroprène 800 quant à elle montre une longueur de propagation du feu de $6,4 - 2,3 = 4,1$ m. Pour illustrer le déroulement d'un essai, on a choisi le cas de cette dernière bande où il y a propagation puis extinction. Dans la figure 2 sont données les évolutions des températures et des concentrations en oxygène et en acide chlorhydrique à 6 m du début de la bande, au niveau de celle-ci ainsi qu'à différentes distances au-dessus du sol.

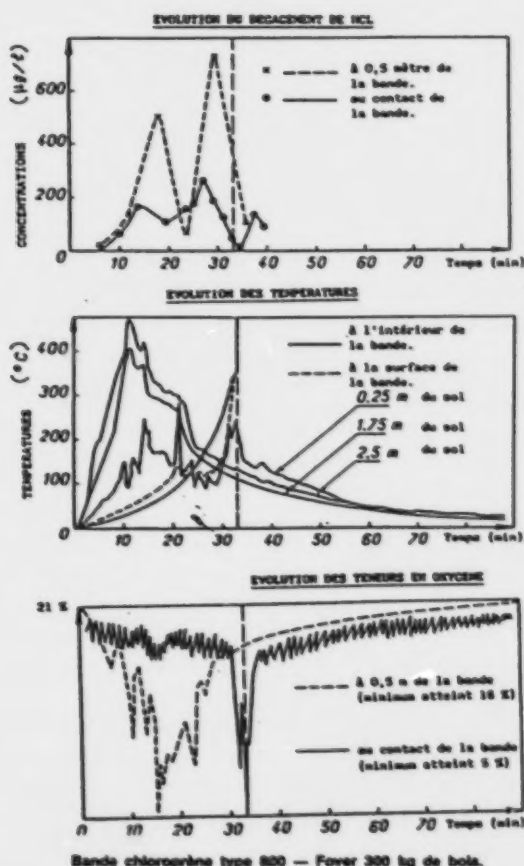


Fig. 2. — Evolution des différentes grandeurs mesurées sur une verticale à 6 m du début de la bande.

L'évolution des températures des gaz montre un maximum qui coïncide avec celui de la combustion du bûcher de bois. On voit que la température maximale est au voisinage de la voûte et qu'elle ne dépasse pas 450 °C, alors qu'à 0,25 m au-dessus de la bande, elle n'est plus que de 250 °C. Les températures sur et dans la bande montrent une élévation progressive qui s'accélère au moment du passage du front de combustion qui détruit les thermocouples. La température dans les gaz à 0,25 m au-dessus de la bande accuse un second maximum au même moment.

La concentration en oxygène des gaz à 0,5 m au-dessus de la bande présente un minimum d'environ 16% qui correspond au moment où la combustion du bûcher est maximale. Au niveau de la bande, le minimum descend à 5% mais n'est atteint qu'au moment du passage du front de combustion sur le tapis.

L'évolution de la concentration en HCl présente deux maximums dont le second est lié au passage du front de combustion à 6 m du début de la bande. On voit que ce second maximum se produit avant celui des températures sur et dans la bande, ce qui signifie que le front de combustion se propage dans un polymère qui a perdu en grande partie son chlore.

Dans le cas des deux bandes en chloroprène où il y a eu propagation, on a pu mettre en évidence une vitesse limite de propagation de l'ordre de 15 à 18 cm/min pour un aérage moyen de 0,85 m/s au-dessous de laquelle le feu s'éteint. On n'a pu déterminer avec précision la température de préchauffage de la bande pour que puisse se produire la propagation, cette température étant probablement comprise entre 250 et 300 °C. Pour la bande en chloroprène 500 qui a brûlé entièrement le bilan thermique au niveau du front de combustion permet d'évaluer une chaleur de réaction apparente qui serait de l'ordre de 350 J/cm².

En ce qui concerne les conséquences des produits de combustion sur l'atmosphère de la galerie, il est difficile d'établir la part respective du bûcher et de la bande dans le dégagement de gaz comme le CO₂ et le CO. Cependant, la comparaison des teneurs moyennes en ces deux gaz montre que la bande en PVC, bien qu'elle n'ait pas propagé, a augmenté sensiblement l'activité du bûcher et donc l'intensité de l'incendie, résultat que l'on retrouve d'ailleurs à partir des puissances thermiques mesurées.

Au niveau du point de mélange, le bilan en acide chlorhydrique est fortement déficitaire en raison de l'importance des condensations de ce composé sur les parois de la galerie. Les concentrations en HCl locales, au voisinage de la bande, peuvent atteindre des valeurs de 400 à 500 ppm.

Les fumées de combustion deviennent rapidement très opaques et envahissent toute la galerie en supprimant toute visibilité sauf dans une bande étroite au-dessus du sol. L'analyse des suies montre qu'en plus de l'acide chlorhydrique absorbé et de composés organo-chlorés, elles renferment des hydrocarbures poly-aromatiques en quantité relativement importante.

5.2. Mousse-urée formol

Les mesures de température à l'intérieur de la mousse permettent de mettre en évidence les différentes phases suivantes de son comportement dans un incendie :

- entre la température ambiante et 150 °C environ a lieu l'évaporation de l'eau et la durée de cette phase est de l'ordre de 2 min 30 s ;
- commence ensuite la décomposition thermique de la mousse avec émission de fumées blanches composées de gaz inflammables qui donnent lieu au phénomène d'embrasement généralisé avec un pic de température

à 900 °C puis un second en fin de période, la durée de la combustion en phase homogène étant de l'ordre de 3 min; — la dernière phase est celle de la combustion du résidu carboné solide laissé par la pyrolyse de la mousse dont la durée est assez imprécise, de l'ordre de 10 min; après l'essai, on constate que le garnissage a complètement brûlé, soit un poids de mousse de l'ordre de 140 kg.

Les mesures de flux total (rayonnement + convection) montrent que la surface de la mousse recevait un éclairage énergétique compris entre 1 et 2 W/cm² au moment où l'inflammation s'est produite.

La composition de la phase gazeuse au contact de la mousse juste avant l'inflammation n'a pas pu être analysée. Cependant des essais en laboratoire ont montré qu'elle pourrait être constituée de méthane (CH₄), d'ammoniac (NH₃) et de méthylamines en plus de CO et HCN.

La composition des gaz au point de mélange montre que les concentrations maximales en CO₂ et CO sont respectivement de 5,9% et 0,4% alors que dans le cas du bûcher de bois seul elles ne dépassent pas 1,8% et 0,03%, les teneurs en oxygène correspondantes étant 15,4% contre 18,8% pour le bois seul.

Au niveau de la mousse, au moment de l'inflammation, la concentration en oxygène tombe à 5% ce qui peut expliquer les teneurs élevées en CO (0,5%) et en HCN observées. La cinétique de dégagement de ce dernier gaz n'a pu être déterminée, l'analyseur se saturant avant le maximum; cependant il a été possible de déterminer la quantité totale de HCN dégagée puisque la méthode de dosage est cumulative; en admettant que la durée de son dégagement soit de l'ordre de 3 min, la concentration en HCN pourrait atteindre 2 300 ppm.

Les oxydes d'azote NO_x (essentiellement NO₂, NO étant négligeable) peuvent atteindre au point de mélange une teneur maximale de 450 ppm.

Quant aux suies et aux goudrons dont le dosage est cumulatif, il est possible de calculer les quantités présentes dans les fumées en faisant l'hypothèse qu'ils se sont dégagés pendant les 3 min qu'ont duré la pyrolyse et la combustion en phase homogène. On trouve ainsi pour les suies 0,56 g/m³_(n) et pour les goudrons 3,5 g/m³_(n).

Enfin, l'analyse par couplage chromatographie-spectrométrie de masse met en évidence la présence de plastifiants du type phényl- et crésyl-phosphate, de dioctylphthalate et de fragments d'urée-formol.

6. CONCLUSIONS

Pour être en mesure d'étudier en grandeur et en situation les problèmes que pose vis-à-vis de la sécurité-incendie l'introduction dans les travaux souterrains de matières et matériaux polymériques nouveaux, le Cerchar a mis en service en 1983 une galerie incendie. Les dispositions adoptées permettent de reproduire la plupart des scénarios d'incendie au fond de la mine et d'examiner le comportement au feu des matériaux mis en place dans les conditions mêmes de leur utilisation.

La dépollution des fumées d'incendie avant leur rejet à l'atmosphère a permis d'implanter cette galerie dans l'enceinte des Laboratoires de Verneuil-en-Halatte et de bénéficier ainsi de toute leur infrastructure scientifique et technique.

Les premiers résultats obtenus sur des bandes transporteuses de type résistant à la flamme et sur une mousse urée-formol montrent qu'en plus de la contribution que ces matériaux polymériques peuvent apporter dans certains cas au développement de l'incendie, les gaz issus de leur dégradation thermique peuvent avoir de graves conséquences sur l'atmosphère de la mine en raison de leur toxicité. De plus, la production de gaz inflammables crée un risque d'inflammation à distance ou d'embrasement généralisé avec certains de ces matériaux.

A la fin de ces recherches, on peut espérer avoir une vue synthétique plus précise du risque potentiel que représente l'utilisation des polymères dans les travaux du fond.

BIBLIOGRAPHIE

- HARTSTEIN A.M. and FORSHEY D.R. — *Coal mine combustion products*. Conveyor belts, Bureau of Mines, RI 8107, 1976.
- HARTSTEIN A.M. and FORSHEY D.R. — *Coal mine combustion products*. Neoprene, polyvinyl chloride compositions, methane foam and wood, Bureau of Mines, RI 7977, 1976.
- SMITH A.F. and KUTHTA J.M. — *Toxic products from burning of fire resistant materials*. Bureau of Mines, Coal Mine Health and Safety Program., Techn. Progress R 66, 1973.
- CROCE P.A., LEE C.K. and NEWMAN J.S. — *An experimental investigation of the fire hazards associated with timber sets in Mines*. Factory Mutual Research Corp., Technical Report RC 80-T-64, serial 22501, 1980.

RISQUE INCENDIE : MATERIELS MINIER

Le CERCHAR pratique les essais suivants pour aider à une meilleure sécurité dans l'utilisation de matériaux polymériques dans les mines.

Matériel de mine.

Courroies transporteuses.

- Approbation selon les directives de l'Organe Permanent de la Communauté Européenne.
 - . Essai en galerie ventilée.
 - . Essai au tambour.
- Contrôle de qualité des bandes transporteuses.
 - . Essai Barthel
 - . Minitunnel DIN 22118.
 - . Indice d'oxygène.

AUTRES MATERIELS

Tuyaux souples pour eau à base de caoutchouc (pression de service 40 bar et 100 bar).	NF M 82470 décembre 85
Tuyaux souples pour air comprimé à base de caoutchouc (pression de service inférieure ou égale à 10 bar).	NF M 82271 décembre 85
Tuyaux souples en caoutchouc pour transmissions hydrauliques.	NF M 82410 septembre 86
Tuyaux en caoutchouc et en plastiques. Mines souterraines. Méthode d'essai d'inflammabilité.	ISO/DIS 8030
Canalisation souples d'aérage, ventubes, type soufflant.	NF M 82011 juillet 87
Canalisation souples d'aérage, ventubes, type aspirant.	NF M 82013
Bacs d'arrêts barrages à eau.	M 82620 juin 87

.../...

FICHES DE SPECIFICATION D'ANTISTATISME ET DE RECTION AU FEU
(spécification interne de CHARBONNAGES DE FRANCE)

Fiche S1 : Revêtements de tambours utilisés dans les installations du fond.

Fiche S2 : Râcleurs de nettoyage et bavettes latérales utilisés dans les installations du fond.

Fiche S3 : Bagues pour rouleaux amortisseurs et revêtements de rouleaux porteurs utilisés dans les installations du fond.

Fiche S4 : Courroies trapézoïdales de transmission utilisées dans les installations du fond.

Fiche S5 : Accouplements élastiques de transmission type pneu.

Fiche S6 : Tuyaux souples destinés aux installations de captage de grisou.

les essais en galerie du **CERCHAR** une installation unique

Le CERCHAR est le Centre d'Etudes et Recherches de Charbonnages de France dont la plus grande partie du personnel travaille dans les laboratoires de Verneuil-en-Halatte dans l'Oise.

Trois grands secteurs d'activité retiennent l'attention de ses chercheurs, ingénieurs et techniciens : le développement des techniques minières, celui des techniques industrielles d'utilisation du charbon et celui de la sécurité minière et industrielle. Dans ce dernier, nous nous sommes particulièrement intéressés aux essais pratiqués dans la galerie d'incendie, installation originale, unique en France, et même en Europe.

**Sécurité industrielle :
des ingénieurs,
des équipements et
des connaissances
à la disposition
de tous les industriels**

Si, lors de sa création en 1947, après la nationalisation des Houillères, le CERCHAR avait pour mission d'étudier les problèmes de recherche scientifique et technique de la profession, il est désormais ouvert à tous les secteurs industriels intéressés par la compétence et l'expérience de ses 500 ingénieurs et techniciens. La recherche en sécurité, tant dans les mines qu'ailleurs, est l'une des activités traditionnelles du centre. L'étude des incendies et des explosions de gaz et de poussières l'ont conduit à se doter d'installations exceptionnelles. Une nouvelle halle d'essais pour les agréments de matériels électriques devant fonctionner en atmosphère explosive, une installation destinée à l'étude des risques liés au stockage et à la manutention des produits pulvérulents et la galerie d'étude en grandeur nature des incendies, pour l'étude des risques d'incendie en milieu confiné.

**La galerie incendie :
des essais en vraie grandeur**

Cette installation, réalisée en 1982, permet d'étudier, dans des conditions voisines de la pratique, les risques d'incendie en milieu confiné et ventilé, comme c'est le cas dans les travaux souterrains. De tels essais intéressent directement la profession minière, mais aussi les industries ou organismes confrontés à des problèmes similaires et les services de la Sécurité Civile.

La galerie, installée à Verneuil-en-Halatte, comprend une partie horizontale de 10 m² de section et d'une cinquantaine de mètres de longueur, suivie d'une partie verticale d'une dizaine de mètres de hauteur et de 6 m² de section. Le débit d'air de ventilation peut atteindre 15 m³/s et le revêtement isolant et réfractaire des parois est prévu pour supporter des températures de 1200 °C et des chocs thermiques importants.

Lors des essais, les fumées et les gaz sortant de la galerie traversent un filtre sec et un laveur à gaz avant d'être rejetés par la cheminée. Cette station d'épuration des gaz permet d'étudier, en plus des incendies de matériaux et de matériels, les problèmes relatifs aux stockages et aux transports des matières inflammables, dangereuses ou toxiques.

Ainsi les trois grands thèmes de recherche qui peuvent faire l'objet d'études dans cette installation sont :

1) La réaction au feu des maté-

riaux, qui implique l'étude des produits de pyrolyse dégagés dans un incendie, du point de vue de leur inflammabilité, toxicité, corrosivité, opacité... et l'étude de leur propagation du feu en tenant compte de l'influence éventuelle d'autres matériaux combustibles présents et pouvant agir comme facteur aggravant.

Il La détection précoce des incendies par utilisation de différents types de détecteurs de flamme, de fumée (ioniques, optiques et thermovélocimétrique).

Il La mise en œuvre des agents extincteurs du feu par l'étude des systèmes d'extinction et celle des conditions d'utilisation des agents courants (poudres chimiques, eau, mousse, composés halogénés, gaz inertes) et ce en fonction de la classe du feu et de l'endroit où il se déclare.

Depuis sa mise en service, l'équipe de M. Lodel chargée de l'étude des problèmes incendie, a conduit des essais pour la mine, sur des bandes de convoyeurs, pour la Sécurité Civile, sur la réaction au feu de panneaux de particules soumis à divers éclaircissements énergétiques, pour E.D.F. sur la tenue des transformateurs à la chaleur avec analyse des gaz de combustion résultant de leur dégradation, et en janvier dernier pour la RATP sur le comportement au feu des stations de ventilation-extraction de l'air chaud.

Simulation d'un incendie dans un tunnel de métro

En cas d'incendie dans un tunnel du métro parisien, les ventilateurs utilisés en fonctionnement normal pour l'extraction de l'air chaud et vicié des installations souterraines pourraient-ils servir pour l'extraction des gaz chauds et des fumées ?

Quelle est la résistance au feu de l'installation en place ? Que faudrait-il changer pour une meilleure performance ? Quelle est

POUR SON FONCTIONNEMENT, LE CERCHAR DISPOSE DE PLUSIEURS RESSOURCES FINANCIERES

Ressources (en millions de francs courants)	Réalisées		Prévues	
	1983	1984	1985	1986
Cotisations professionnelles et autres ressources	89	114	167	145
Aide de la CECA	13	9	10	12
Subvention du Ministère du Redéploiement Industriel et du Commerce Extérieur	56	60	63	65
CIDF - Chimie et SAV	34	41	44	48
Recettes commerciales	45	38	36	55
Total	237	262	320	325



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Le système de détection et d'extinction automatique « Compact Halon » permet une installation rapide, économique et esthétique dans les petites salles informatiques, laboratoires, ateliers de montage, etc...

De conception modulaire, le « Compact Halon » est constitué :

- d'une armoire en tôle acier renfermant le contrôle de détection / extinction et le réservoir de gaz Halon.
- d'un réseau d'au moins deux détecteurs de fumée
- d'avertisseurs sonores et lumineux d'évacuation.

La détection est assurée par un contrôle à deux seuils d'alarme.

Après un délai maximum de 30" le halon est diffusé dans le local protégé.

Le réservoir XPS chargé à 15-30-45 ou 80 litres de halon 1300 E est équipé de la valve VT avec position test qui assure une haute fiabilité du système par simulation périodique du fonctionnement complet sans perte de gaz Halon.



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CERCHAR

L'influence du refroidissement apporté par des sprinklers utilisés en phase dynamique ?

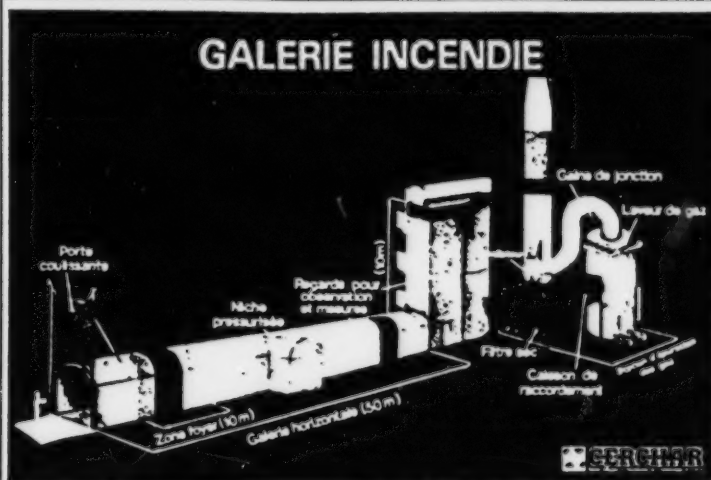
Telles étaient les questions auxquelles la RATP souhaitait une réponse sûre et précise en s'adressant au service de M. Lodel. Ces essais ont été pratiqués après un mois d'études théoriques et de préparation de la galerie, le 22 janvier dernier. Ils portaient sur l'ensemble d'une installation type de ventilation de métro avec tests de la tenue en température des différents équipements : électriques, mécaniques, acoustiques et aérodynamiques la composant.

L'essai en grandeur nature a duré toute la journée. L'alimentation en gaz chaud de la galerie était assurée par un brûleur à propane liquide de 15 MW (!) installé à l'entrée de la galerie, installation importante du type torchère à multiples injecteurs. La simulation des mises en défaut des éléments électriques et le doublage de ces équipements par des matériels plus performants, et plus résistants, ont permis de suivre au fur et à mesure l'apparition des défauts, et de noter très précisément les dysfonctionnements des divers composants sans pour autant interrompre le cours de l'essai et le fonctionnement du moto-ventilateur (le remplacement de ce dernier avait, bien sûr, été prévu, mais il n'a pas été nécessaire).

En outre trois sprinklers placés à une vingtaine de mètres en aval du ventilateur ont permis d'évaluer l'importance du refroidissement apporté par une pulvérisation d'eau sur la veine de gaz chaud.

Les mesures de température étaient assurées par 25 capteurs installés aux différents points stratégiques de la galerie. L'ensemble des relevés de température, les simulations de défauts des différents appareils et de la mise en fonctionnement des installations relais étaient gérés et enregistrés par ordinateur.

L'objectif retenu était de prévoir les modifications à envisager pour porter ces installations de ventilation existantes à un niveau de sécurité



A Schéma de la galerie d'incendie CERCHAR à Vernueil-en-Halatte (Oise).

Les parois de cette galerie incendie sont constituées par un béton composite réfractaire et isolant, conçu pour supporter des températures de 1200°C et des chocs thermiques élevés.



rité donné supérieur, soit une optimisation du rapport coût-sécurité, objectif pleinement atteint au cours de ces essais.

Bientôt : simulation d'un incendie dans un tunnel routier

Le CERCHAR envisage de réaliser

des essais, toujours en vraie grandeur, d'un incendie de voiture et caravane bloquées dans un tunnel routier. Quels sont les risques réels encourus par les automobilistes ? Et quelles sont les possibilités d'intervention des équipes de secours et d'évacuation du public ? La réponse dans quelques mois, ce thème d'étude est en projet.

Danielle Rambeau

POUR EN SAVOIR PLUS SUR LE CERCHAR

Le CERCHAR est prestataire de services en études et recherches, essais, travaux de contrôle, agrément de matériel, missions de conseil, analyses, aides à la réalisation de prototypes, expérimentations sur maquettes et unités pilotes, formation de spécialistes.

Ses services apportent réponses aux problèmes suivants :

☐ Techniques d'exploitation minière :

Planification des travaux. Pressions de terrains et stabilité des ouvrages. Aérage. Destruction de roches. Perfectionnement des machines. Applications minières de l'électronique et de l'hydraulique.

☐ Sécurité minière et industrielle :

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☐ Lutte contre les nuisances :

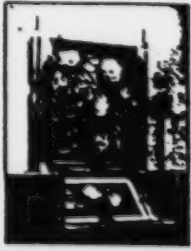
Pollution atmosphérique et odeurs. Lutte contre les poussières nocives. Recherches biologiques sur les affections pulmonaires dues aux polluants. Acoustique industrielle.

☐ Et :

Applications industrielles de l'électronique. Analyses physico-chimiques fines et complexes. Essais sur matières plastiques et matériaux divers.

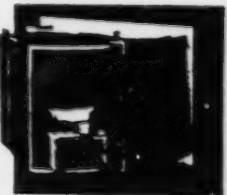


Lors des essais du 22 pour les conditions d'incendie et/ou simulées par un brûleur à propane liquide de 15 MW

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EVOLUTION DES SYSTEMES D'ISOLATION DANS LES TRANSFORMATEURS DE DISTRIBUTION EN RELATION AVEC L'AMELIORATION DU COMPORTEMENT AU FEU

G. LE ROY

- F. SANDOZ

Electricité de France - GIMELEC

INTRODUCTION

La sécurité des usagers et des installations dans certains types de bâtiments comme les établissements recevant du public (ERP), ou les immeubles de grande hauteur (IGH) est un souci majeur et justifie une stricte réglementation relative aux risques d'incendie que pourraient apporter les transformateurs de distribution qui les équipent.

Jusque là, les seuls critères considérés comme essentiels pour choisir le type de transformateur pouvant satisfaire ces exigences étaient les notions de "non inflammabilité" et "non propagation" de l'incendie appréciées par la mesure du point de feu.

Ces dispositions ont conduit à installer des transformateurs isolés aux askarels -diélectriques réputés ininflammables- ou, dans les étages d'I.G.H. en particulier, des transformateurs de type sec.

Mais les seuls askarels disponibles alors contenaient des PCB (polychlorobiphényles) et depuis déjà quelques années, à des échéances variables d'un pays à l'autre, leur emploi s'est vu progressivement freiné, puis strictement réglementé, voire interdit, pour deux motifs : la non biodégradabilité et la bioaccumulabilité des PCB.

Parallèlement, et suite à l'expérience acquise à l'occasion de divers accidents, les exigences des utilisateurs relatives au comportement au feu des matériels électriques ont évolué. Il est vrai qu'aujourd'hui les seules notions "officielles" d'ininflammabilité et de non propagation de la flamme sont insuffisantes. Tout diélectrique peut en effet "brûler" il suffit de le porter à température suffisamment élevée.

En ce qui concerne les transformateurs, il apparaît commode de classer les diélectriques vis à vis du risque d'incendie sous deux aspects distincts :

- en fonction de leur aptitude ou non à générer un incendie en cas de défaut dans le transformateur,
- en fonction de leur comportement dans un incendie ayant une autre source que le transformateur lui-même.

Partout où il est exigé des performances spéciales vis-à-vis du feu (dans les E.R.P. ou I.G.H., par exemple), il est clair que seuls les diélectriques ne pouvant eux-mêmes être à l'origine d'un incendie peuvent être admis.

Parmi ceux-ci nous trouvons les isolants réputés ininflammables (askarels, isolation sèche,...) auxquels on peut espérer associer (sans toutefois que ceci soit parfaitement établi) les isolants difficilement inflammables : silicones, esters, etc... En revanche, les huiles minérales n'entrent pas,

bien sûr, dans cette catégorie.

Si la condition d'être non initiateur d'un incendie est nécessaire, elle est loin d'être suffisante. Le comportement du transformateur dans l'incendie est au moins aussi important. Suivant le cas, on peut exiger, par exemple, qu'il n'y ait pas dégagement de fumées toxiques, corrosives ou opaques, tous points fondamentaux quant à la possibilité d'évacuer ou de secourir les personnes. Mais également la chaleur dégagée par la combustion éventuelle du diélectrique du transformateur ne doit pas être trop forte afin de ne pas favoriser la propagation de l'incendie.

Différentes recherches vers des produits présentant un bon comportement au feu ont donc été lancées concernant, soit des askarels sans PCB (dénommés en France L.I.N.T. ou Liquides Isolants Halogénés pour Transformateurs) comme l'UGILEC T, soit des diélectriques moins performants au plan de l'ininflammabilité mais ayant vis à vis du feu certaines propriétés intéressantes comme les huiles silicones et les esters.

Enfin, de notables progrès ont été accomplis dans la technique des transformateurs secs de façon, en particulier, à améliorer leur comportement dans un environnement hostile, (humidité, poussières) et les rendre économiquement plus concurrentiels.

Dans le but d'éclairer l'utilisateur potentiel dans le choix d'un appareil satisfaisant au mieux ces exigences, nous nous sommes attachés à établir une comparaison de ces diélectriques sur la base de certaines caractéristiques relatives à leur comportement au feu ou ayant une incidence sur la conception des transformateurs.

Les caractéristiques des matériaux ne pouvant donner qu'une idée limitative du comportement au feu des matériels les utilisant, EDF a jugé nécessaire de compléter cette comparaison par des essais de transformateurs dans des conditions simulant d'aussi près que possible un incendie réel.

Mais n'oublions pas que ces produits ont été étudiés suite à la perspective d'interdiction frappant les askarels. Il est donc également nécessaire de les examiner au plan de leur interaction avec l'environnement, en prenant en particulier en compte les problèmes de leur récupération ou de leur destruction en fin d'exploitation du transformateur.

TRANSFORMATEURS DU TYPE IMMERGE

Parmi les principaux liquides diélectriques de substitution aux askarels avec P.C.B., on peut citer : les huiles à poids moléculaire élevé, les huiles silicones, les esters, les

hydrocarbures linéaires chlorés, les hydrocarbures aromatiques chlorés (ex. perchloréthylène UGILEC T).

Les constructeurs français ont déjà acquis une certaine expérience avec les huiles silicones, les esters et l'UGILEC T. Le tableau I donne les principales caractéristiques de ces liquides, particulièrement celles qui sont liées au comportement au feu, comparées à celles des huiles normales et des huiles lourdes.

Essais de compatibilité et de vieillissement

En complément aux essais réalisés par les fabricants de liquides diélectriques, de très nombreux essais de compatibilité et de vieillissement ont été effectués au Laboratoire Central des Industries Électriques, à E.D.F. et chez les constructeurs, plus particulièrement pour l'UGILEC T dont la mise au point est assez récente.

Ils ont porté sur les divers constituants et aussi sur les accessoires immergés, dont les traversées et les commutateurs hors tension, pour vérifier que le contact entre le liquide diélectrique et le matériau immergé ne dégradait ni l'un ni l'autre.

En outre, des essais de longue durée plus complexes ont été réalisés sur des maquettes d'enroulement à échelle réduite ou en vraie grandeur de manière à simuler les différentes contraintes simultanées auxquelles sont soumis ces constituants dans un transformateur : contraintes mécaniques, électriques

et thermiques.

Les résultats obtenus à ce jour sont satisfaisants.

Considérations technologiques

L'une des préoccupations de chaque constructeur de transformateurs, après avoir vérifié la compatibilité avec les matériaux, est d'examiner la compatibilité avec ses standards de fabrication.

Compte tenu des propriétés des différents diélectriques, on peut être amené à des technologies différentes.

Propriétés thermiques et physiques. La transmission de chaleur dans les transformateurs refroidis par un diélectrique liquide dépend des paramètres suivants : viscosité, conductibilité thermique, chaleur spécifique, coefficient de dilatation. Elle est d'autant meilleure dans une configuration donnée que la viscosité est faible et les autres paramètres aussi élevés que possible.

a) cas de l'huile lourde: Du fait de la viscosité, des dispositions particulières sont à prévoir dans le dimensionnement des canaux de refroidissement des bobinages, et dans la conception de la cuve en ce qui concerne les radiateurs ou les ondes placés sur son pourtour.

b) Cas de l'huile silicone: La remarque du cas précédent s'applique aussi, mais avec une incidence moindre sur la construction qui, toutefois, demeure spéciale.

TABLEAU I - Propriétés de divers liquides diélectriques

PROPRIÉTÉS	huiles normales Classe II	huiles lourdes	huiles silicones	Esters	Ugilec T
Thermiques					
Point d'éclair °C	130-160	210-285	> 300	257	140
Point de feu °C	165-180	310-320	360	310	Néant jusqu'
Point d'auto-allumage °C	330	540	405-435	405-435	à ébullition
Point d'écoulement °C	- 45	- 30	- 35	- 30	< - 30
Conductivité thermique W/m.K	0,132	0,130	0,131	0,165	0,109
Chaleur spécifique kJ/Kg.K	1,93	1,93	1,51	1,81	1,09
Chaleur de combustion kJ/g	46	46	28	33	/
Chaleur convective kW/m ²	/	346	55-65	377	< 50
Chaleur radiative kW/m ²	/	361	25-49	116	< 25
Coefficient de dilatation 10 ³ /K	0,75	0,75	1,04	0,69	0,75
Indice d'oxygène	16	24	23	22	> 55
Physiques					
Masse volumique à 25°C kg/m ³	≤ 895	880	960	960	1420
Tension interfaciale à 25°C dyne/cm	46	45	51	38	50
Viscosité mm ² /s ou cst à 25 °C	11-18	350	50	65	9
100 °C	1,5-3	16	14	4	1,5
Diélectriques					
Constante diélectrique à 25 °C	2,2-2,4	2,4	2,7	3,2	5,1
Rigidité diélectrique à 25 °C (CEI 156) kV	60	45	50	55	56

c) Cas de l'ester: Les précautions à prendre pour la transmission de chaleur sont moins importantes que pour les fluides précédents.

d) Cas de l'UGILEC T: La conductivité thermique et la chaleur spécifique sont un peu plus faibles que pour les huiles normales; cela n'a pas d'incidence pratique sur la construction qui reste normale.

Compte tenu des points de feu nettement plus élevés pour les liquides diélectriques considérés, on pourrait admettre des échauffements supérieurs à ceux qui sont spécifiés par les normes pour l'huile normale à condition d'utiliser des isolants de classe supérieure à ceux de la classe A et de vérifier le comportement des matériaux et accessoires pour ces nouvelles conditions.

Influence du coefficient de dilatation :

Le coefficient de dilatation, pratiquement le même pour tous les liquides diélectriques, est supérieur d'environ 40% pour les huiles silicones. Pour un même échauffement, il y a donc lieu de tenir compte de l'accroissement de volume supplémentaire, soit au niveau du conservateur, soit au niveau de la pression résultante dans le cas des transformateurs hermétiques. A noter que dans le cas des cuves à ondes la pression est absorbée par un dimensionnement correct des ondes déformables sous l'action de cet accroissement de volume.

Propriétés diélectriques. Ces liquides diélectriques absorbent beaucoup plus d'humidité que l'huile normale et, bien que leur rigidité diélectrique soit moins sensible à la teneur en eau, il est important de se prémunir contre la pénétration de l'humidité au stockage, lors du traitement et en service.

Les transformateurs à remplissage total, pour lesquels le liquide diélectrique n'a aucun contact direct avec l'air ambiant, présentent de ce point de vue un avantage certain.

TRANSFORMATEURS DU TYPE SEC

Ces transformateurs sont actuellement construits suivant deux types de technologie caractérisés par le mode de protection des

bobinages.

a) Transformateurs imprégnés. Les bobinages sont protégés par un vernis. L'opération de vernissage, effectuée sous vide, permet une bonne imprégnation du matériel. Les épaisseurs déposées sont de l'ordre de quelques dixièmes de millimètre. Les principales fonctions du vernissage sont l'agglomération des bobinages et la limitation des effets des agressions externes : poussières, humidité. Les isolants utilisés ont en général un indice de température de 130 à 220°C. Cette technologie est utilisable jusqu'à 8-10 MVA et des tensions de 20 kV (essai 30 kV une minute, 93 kV au choc en onde pleine).

b) Transformateurs enrobés.

Le bobinage MT est protégé par une résine d'enrobage. L'opération est là aussi effectuée sous vide, permettant une bonne imprégnation et l'obtention de bobines exemptes de décharges partielles.

Les épaisseurs de résine sont de l'ordre de quelques millimètres. Les résines utilisées sont en général d'indice thermique 130 ou 135°C.

L'enrobage apporte un excellent maintien mécanique des bobinages, une très bonne résistance aux courts-circuits francs, une protection efficace contre les agressions externes, particulièrement utile dans le cas d'un environnement très pollué. Cette technologie permet d'améliorer la tenue aux surtensions (125 kV au choc O.P.).

Le choix des matériaux est fait en considérant à la fois leurs caractéristiques diélectriques, mécaniques et physiques, leur endurance thermique et leurs caractéristiques de tenue au feu.

Pour évaluer ces dernières, les constructeurs se sont jusqu'ici appuyés sur des résultats d'essais sur éprouvettes.

Différentes méthodes de laboratoire permettent de déterminer les caractéristiques d'inflammation et de propagation. Le principe de l'essai consiste généralement à soumettre l'échantillon à l'action d'une source de chaleur bien définie, dans des conditions spécifiées.

La représentativité relative de l'essai réside dans la définition des différents paramètres de mise en oeuvre.

Mais les critères d'appréciation de ces

TABEAU 2 - Caractéristiques d'isolants pour transformateurs de type sec

MATERIAUX	INDICE LIMITE D'OXYGENE	
	A 20°C	A 200°C
Stratifié, mat de verre, polyester	21	11
Stratifié, mat de verre, polyester autoextinguible	29 à 38	28 à 38
Stratifié, mat de verre, époxyde	31	18
Stratifié, tissu de verre, époxyde	26	14
Ruban samica, sillonne, silicone	70	67

méthodes sont parfois difficiles à interpréter.

La méthode de l'indice limite d'oxygène permet, elle, d'évaluer les conditions d'environnement d'inflammation qui provoquent sur tous les matériaux le même effet, sans fournir la réponse du matériau à une contrainte spécifique.

Elle est une méthode quantitative permettant d'établir un classement scientifique des isolants.

Le tableau 2 permet de concrétiser la différence de comportement de différents isolants, ainsi que l'influence de la température du matériau lors de l'essai.

Les spécifications de composition, les taux de charge en matières inertes, l'interaction de celles-ci, l'addition d'agents ignifugeants, expliquent les différences observées. Si les valeurs à 20°C sont relativement élevées, celles relevées à 200°C traduisent une augmentation de l'inflammabilité, non négligeable avec la température pour certains matériaux.

Il est important de considérer également les gaz émis lors de la combustion. Les matériaux synthétiques des transformateurs secs dégagent essentiellement les oxydes de carbone et des hydrocarbures légers. A haute température, des essais, bien que menés suivant une méthode encore expérimentale, ont mis en évidence des matériaux présentant des dégagements d'acides :

- Stratilite mat de verre, polyester autoextinguible : la présence d'ignifugeant peut expliquer la formation, à 700°C, d'acide chlorhydrique (environ 4 % en poids du matériau solide) et de quelques traces d'acide cyanhydrique.

- Nomex, papier synthétique polyamide : sa composition conduit, à 700°C, à des dégagements abondants de gaz et à la formation d'acide cyanhydrique (environ 2% en poids).

- Certaines époxydes utilisées en enduction d'isolants en film : leur durcisseur aminé conduit à 700°C à la formation de traces d'acide cyanhydrique.

Seuls les essais en vraie grandeur sur transformateurs permettent d'évaluer l'incidence réelle de l'emploi de ces matériaux, compte-tenu de leurs masses relatives dans l'appareil.

ETUDE COMPARATIVE DU COMPORTEMENT AU FEU DE TRANSFORMATEURS DE DISTRIBUTION DE DIFFÉRENTES TECHNOLOGIES

Des essais grandeur réelle de comportement au feu de transformateurs de distribution ont pu être réalisés grâce à la construction récente par les laboratoires des Charbonnages de France (CERCHAR) d'une "galerie incendie" garantissant contre tout risque de pollution de l'environnement.

Cette galerie, ventilée, est munie d'un dispositif d'épuration des fumées par filtrage et lavage, et peut être équipée d'appareils de contrôle et de mesure pendant la phase incendie - dispositifs de prélèvement de gaz et de suies, fluxmètres, opacimètres, relevés de température, etc... reliés à une centrale de mesure. De l'extérieur on peut également filmer l'incendie.

Choix des transformateurs essayés

La raison majeure ayant initié cette campagne étant l'abandon des askarels contenant des PCB, il aurait été souhaitable, comme référence, de faire un essai sur un transformateur utilisant ce type de diélectrique. Compte tenu des risques potentiels de dégagement de produits hautement toxiques lors de la combustion des PCB, le principe de cet essai n'a pas été retenu.

Cependant, des essais comparatifs de combustion à différentes températures ont été réalisés sur des échantillons d'un askarel contenant des PCB et d'un nouveau diélectrique n'en contenant pas : l'UGILEC T. Le transformateur à huile minérale n'a pas non plus été testé son comportement ayant été jugé suffisamment connu.

Ont finalement été retenues les technologies dont on avait déjà une expérience suffisante et présentant, vis-à-vis du feu, le plus d'intérêt a priori :

- 2 transformateurs de type sec, non enrobés, de classes d'isolation différentes (B et H),

- 1 transformateur isolé à l'UGILEC T, nouveau diélectrique proposé par PRODELEC du type askarel mais sans PCB. De propriétés voisines, il n'en possède pas les inconvénients vis-à-vis de l'environnement (non biodégradable et bio accumulable). En revanche, c'est encore un diélectrique chloré.

- 1 transformateur à l'huile silicone, diélectrique non strictement ininflammable mais ayant l'avantage, a priori, d'être non chloré.

Principes et paramètres de l'essai

Un incendie se caractérise par deux éléments essentiels :

- de la chaleur transmise à l'environnement par rayonnement, convection et conduction,
- des flammes pouvant lécher les objets voisins en favorisant leur inflammation.

Des essais préliminaires ont été réalisés afin de déterminer les solutions rendant le mieux compte des phénomènes tout en permettant une reproductibilité suffisante des essais.

On a finalement utilisé des panneaux électriques rayonnants (2 x 70 kW) en conjonction avec des rampes à gaz de faible énergie (flames pilotes) pour simuler les flammes. Un flux thermique total sur la surface du transformateur en essai de 3,5 W/cm² a ainsi pu être atteint.

Pour chaque essai ces panneaux ont été mis en service 40 min, l'instant de leur allumage ayant servi de référence de temps pour l'expression de certaines grandeurs caractéristiques du comportement des divers transformateurs.

Par ailleurs, pour se rapprocher des conditions d'exploitation réelles, le transformateur était préchauffé électriquement avant essai, dans ses conditions nominales d'emploi. De même, pour les transformateurs à diélectrique liquide, une tige de diélectrique était présente dans une cuve de rétention disposée sous le transformateur (conséquence d'une fuite).

Synthèse des conclusions essentielles et commentaires

A la date de rédaction de ce rapport, tous

les résultats de mesure n'ont pu être explicités; les conclusions qui suivent sont donc partielles et seront complétées lors de la présentation. Néanmoins, elles ne manquent déjà pas d'intérêt, comme on peut en juger d'après le tableau 3.

On y a reporté certaines grandeurs caractéristiques de l'aspect "combustible" du transformateur :

- pourcentage de l'isolation ayant effectivement "brûlé",
- quantités dégagées pour certains produits de combustion (CO_2 , HCl , poussières et suies),
- énergie totale dégagée dont participation du transformateur,
- durée d'insensibilité à l'incendie du transformateur,
- durée de combustion totale du transformateur (sous et hors effet des panneaux radiants le cas échéant).

Les valeurs de ce tableau rendent bien compte du comportement des différents appareils essayés :

- transformateur sec classe H : seuls des effets légers se sont manifestés au bout d'un certain temps : pyrolyse des vernis superficiels, des peintures des armatures métalliques, quelques flammes en haut des cylindres isolants entre MT et BT. L'arrêt des panneaux radiants a stoppé immédiatement ces effets et leur remise en route n'a pas permis un rallumage des flammes. Notons que ce bon comportement est une conséquence du choix des matériaux qui s'est fait, sur cet appareil, sur la base d'essais au feu systématiques sur échantillons (indices d'oxygène à différentes températures, analyse des gaz de combustion...).

- transformateur sec classe B : contrairement au précédent, le comportement de cet appareil a été plutôt décevant et même, dans une certaine mesure, surprenant.

Environ 3 min après son exposition au feu, alors que la température atteinte était de l'ordre de 130°C , le transformateur s'est enflammé (combustion des gaz dégagés par la pyrolyse des vernis).

Malgré l'arrêt des panneaux radiants après 17 min, la combustion s'est auto-entretenue jusqu'à destruction complète des isolants (durée totale une heure). Cet incendie du transformateur est cependant resté relativement modéré, sans dégagements de fumées ni d'énergie très élevés, ce qui s'explique compte tenu du faible volume de combustible mis en jeu.

- transformateur à l'huile silicone : l'essai de cet appareil a réellement créé la surprise. Nous connaissions les silicones pour avoir une réaction au feu plutôt satisfaisante compte tenu de la formation d'une couche de silice protectrice. Si ce comportement est vrai dans le cas d'une flaque enflammée dans les conditions d'essais réalisées jusque là (essais des Factory Mutuals aux USA, par exemple) il s'est révélé tout à fait différent dans nos propres conditions d'essais visant à simuler un incendie réel (dans des conditions peut-être extrêmes, il est vrai).

L'échauffement du transformateur s'est traduit par une élévation de sa pression interne suffisante pour qu'il y ait projection de silicone par les joints sous forme d'aérosol.

Il y a eu alors embrasement complet du transformateur sous une forme particulièrement spectaculaire.

La combustion du silicone s'est traduite par la production d'un épais nuage de silice qui s'est déposé en une couche poreuse de plusieurs centimètres dans toute la galerie et sur le transformateur lui-même. Ce der-

TABLEAU 3 - Réaction au feu de différents types de transformateurs

Type de transformateur	Sec classe H 630 kVA	Sec classe B 400 kVA	Silicone 230 kVA	UGILEC T 230 kVA
Masse de liquide cuve/bac				
Premières manifestations	30 min	3 min	30 min	20 min
Fin d'incendie	40 min	70 min	110 min	55 min
Energie totale récupérée à 12 m du foyer (40 min / 60 min)	225 MJ / 225 MJ	600 MJ / 640 MJ	700 MJ / 4 900 MJ	400 MJ / 300 MJ
Energie émise par les panneaux radiants	336 MJ	143 MJ*	336 MJ	336 MJ
Part du transformateur à l'énergie totale	<1%	30%	93%	33%
Pourcentage de destruction du combustible	20%	100%	100%	20%
Masse de CO_2 dégagée	10 kg	100 kg	300 kg	75 kg
Masse d' HCl dégagée				25 kg
Masse de suies et poussières	0,15	0,5 kg	180 kg	1,5 kg

* panneaux coupés compte-tenu de l'évolution de l'incendie

nier s'est trouvé enveloppé d'une gangue, qui, au lieu d'étouffer l'incendie, a pu le favoriser en limitant les pertes calorifiques.

Malgré l'arrêt des panneaux radiants, la combustion s'est entretenue jusqu'à épuisement quasi complet du diélectrique.

Le transformateur aux huiles silicones, comme tout transformateur immergé d'ailleurs, apparaît relativement résistant au feu tant que les conditions sont insuffisantes pour entraîner l'ouverture de la cuve par rupture ou fuite aux joints. En cas contraire, lorsque l'incendie est particulièrement violent, le comportement de cet appareil rend pratiquement impossible toute intervention : fort dégagement de chaleur favorisant la propagation de l'incendie, projection d'un nuage de silice pulvérulente à haute température interdisant toute visibilité.

Remarquons cependant qu'aucune substance toxique ou corrosive n'est produite, ce qui autorise une intervention après incendie sans autre précaution que l'usage d'un masque anti-poussières.

- Transformateur à l'UGILEC T : Cet appareil s'est révélé bien résistant au feu. Le diélectrique lui-même ne "brûle" pas comme l'huile silicone mais se décompose plutôt une fois porté à température suffisante. Lors de l'essai, l'échauffement du transformateur a néanmoins été suffisant pour entraîner la rupture de la cuve. Il y a alors eu combustion du diélectrique mais sans dégagement calorifique notable et qui s'est arrêté rapidement après l'extinction des panneaux radiants. Ce transformateur ne favorise donc pas la propagation de l'incendie. En revanche, sa combustion produit des gaz de décomposition corrosifs (HCl) et nocifs (organochlorés) nécessitant des équipements spéciaux pour les équipes de lutte contre l'incendie et une protection des installations. Néanmoins, ces gaz ne contiennent pas de produits hautement toxiques, ce qui confirme les résultats obtenus lors des essais sur échantillons.

CONCLUSION

On constate, au cours de ces dernières années, une progression générale vers un meilleur comportement au feu des transformateurs, ceci grâce aux études de nouveaux matériaux et à leur mise en oeuvre, et grâce aux essais pratiqués sur échantillons. Toutefois les récents essais d'incendie en vraie grandeur ont montré qu'il restait encore beaucoup à faire pour maîtriser complètement le sujet.

L'interprétation des résultats de ces essais doit être conduite avec prudence en prenant garde de ne pas généraliser trop hâtivement. En effet, d'autres conditions réelles d'incendie pourraient entraîner des comportements relatifs différents ; d'autre part, il est bien évident que l'on ne peut étendre les conclusions de ces essais à tous les transformateurs de chacun des quatre types testés, à cause des écarts technologiques existant en fait à l'intérieur de ces catégories.

Néanmoins l'utilisateur peut dès maintenant

tenir compte de ces résultats pour compléter ses critères de choix.

A priori on ne peut rejeter aucun des types de transformateurs essayés, leur choix résultant d'une définition précise des exigences réelles liées aux conditions d'emploi.

D'une manière générale, les transformateurs secs présentent des risques réduits du point de vue propagation du feu et nocivité des produits de combustion à cause de la faible quantité relative de matériaux organiques employés.

Ils sont malheureusement pénalisés par leur prix, en particulier l'appareil de classe H, le seul à avoir donné entière satisfaction lors des essais au feu grandeur réelle.

Quant aux transformateurs immergés, le choix doit se faire suivant la priorité exigée. Si le risque de propagation d'incendie doit être totalement exclu, l'UGILEC T est la meilleure solution malgré le dégagement de vapeurs nocives.

Si le risque de propagation est moindre et que, d'autre part, on attache la plus haute importance à l'absence de produits de décomposition nocifs, les huiles silicones ou les esters sont alors une bonne solution. Bien entendu, l'utilisateur prend aussi en considération les divers coûts correspondant à une solution : l'appareil lui-même, les pertes capitalisées, l'installation et l'assurance.

Les essais sur du matériel en vraie grandeur nécessitent une installation très spéciale - celle du CERCHAR est unique au monde -. Ils sont très coûteux et ne peuvent être pratiqués que sur un nombre très limité d'appareils ; actuellement, seul est prévu en complément l'essai d'un transformateur du type sec enrobé.

Il apparaît donc indispensable de développer de nouveaux essais sur composants plus représentatifs des conditions d'incendie réel. Toutefois le besoin urgent d'une réglementation sur l'emploi des différents diélectriques liquides justifie la poursuite des travaux de normalisation en cours.

En France, ceux-ci portent sur un classement de ces diélectriques et sur l'établissement d'un document U.T.E. pour caractériser les L.I.M.T. (liquides isolants halogénés pour transformateurs) ; cette dernière norme sera applicable, entre autres produits, à l'UGILEC T.

REFERENCES :

- 1 - "Les installations et le matériel électrique face à l'incendie", R.G.E., 1984 - N° 7 - 8, 431 - 432 ;
- 2 - "Galerie Incendie", documentation CERCHAR Industrie.
- 3 - "Méthodes de laboratoire pour apprécier le comportement au feu des matériaux synthétiques". Norme EDF HN 29 E 40.
- 4 - "Liquides isolants Halogénés pour Transformateurs". Norme RFC 27 - 120.
- 5 - G. METZGER et M. PARIS - "Indice d'oxygène et comportement au feu des matériaux synthétiques utilisés en diélectrotechnique". Caoutchoucs et plastiques n° 581 06/07/1978

Le CERCHAR étudie le comportement au feu d'une installation de ventilation de la RATP

par R. LODEL (*) et D. GABAY (**)

1. Introduction. Objectif des essais

A partir des années 1960, la RATP a lancé un grand programme d'amélioration et de rénovation du métro parisien. La capacité de transport s'est fortement accrue par la mise en exploitation de matériels plus performants, par la création du Réseau Express Régional (R.E.R.) et par la mise au point de nouvelles techniques d'exploitation permettant une augmentation de la fréquence des rames. Cet effort de modernisation a été mené avec le souci permanent d'améliorer le confort de l'usager sans compromettre sa sécurité. Parallèlement, un programme de rénovation des stations a été mis en place.

L'accroissement du trafic s'est traduit par une forte augmentation des dégagements de chaleur et, pour remédier aux conséquences de ceux-ci sur le confort bioclimatique des stations et rames du métro et du R.E.R., la RATP a entrepris, à partir des années 1970, un vaste programme de rénovation et de renforcement de la ventilation mécanique.

Actuellement, le nombre de ventilateurs de confort installés en tunnel est d'environ 220 sur le métro et de 50 sur le R.E.R. De plus, il faut noter que dans le R.E.R. une soixantaine de ventilateurs permettent d'améliorer l'ambiance des salles d'échanges et des accès.

A la suite de divers incidents survenus en tunnel, il est apparu que le danger principal en cas d'incendie serait représenté par les fumées dont on sait que le dégagement peut provoquer l'asphyxie des personnes et une diminution importante de la visibilité souvent à l'origine des effets de panique.

C'est dans ce contexte qu'il est apparu intéressant d'envisager l'utilisation des ventilateurs de confort pour assurer éventuellement le *désenfumage des tunnels et des quais*.

Des essais ont été menés sur le réseau afin de mieux connaître et donc de maîtriser les mouvements d'air en cas d'incendie ; ils ont permis la définition d'un guide d'action sur la ventilation (« Guide opérateur

désenfumage ») à l'usage exclusif des responsables du réseau ferré et des sapeurs pompiers de Paris.

Il est dès lors apparu primordial, compte tenu de cette fonction nouvelle des ventilateurs, d'évaluer leurs tenues à la température. Dans ce but, un poste de ventilation de type métro a été essayé dans la galerie expérimentale du CERCHAR. Ce poste y a été reconstitué dans son intégralité, comprenant aussi bien le groupe motoventilateur que les commandes, câbles et accessoires (insonorisants, volets coupe-vent, etc.).

Un générateur de fumées chaudes, placé en amont du poste, permet d'alimenter le ventilateur en essai avec des gaz à température réglable.

2. Description des essais

2.1. Présentation de la plate-forme d'essais du CERCHAR

Le CERCHAR a réalisé une galerie expérimentale d'essais en vraie grandeur permettant l'étude du comportement au feu de matériaux et de systèmes complexes ainsi que l'évaluation de dispositifs de détection et de protection.

La galerie comprend une partie horizontale de 10 m² de section, longue de 50 m suivie d'une partie verticale de 6 m² de section et de 10 m de hauteur (voir figures 1 et 2).

Elle est constituée par un assemblage de viroles en acier garnies intérieurement d'un revêtement en béton réfractaire isolant conçu pour supporter des températures de 1 200 °C et résister à des chocs thermiques importants.

Différents scénarios d'incendie peuvent y être simulés, soit en régime statique dans des volumes confinés, soit en régime ventilé. La galerie fonctionne, dans ce dernier cas, en dépression et elle a été munie de tous les dispositifs nécessaires pour réduire le plus possible la pollution extérieure liée au rejet des produits de combustion.

2.2. Installation du ventilateur d'essai dans la galerie

2.2.1. Description sommaire d'un poste de ventilation de type métro

Un poste de ventilation comprend généralement

— le groupe motoventilateur à accouplement direct (débit moyen de 60 m³/s) ;

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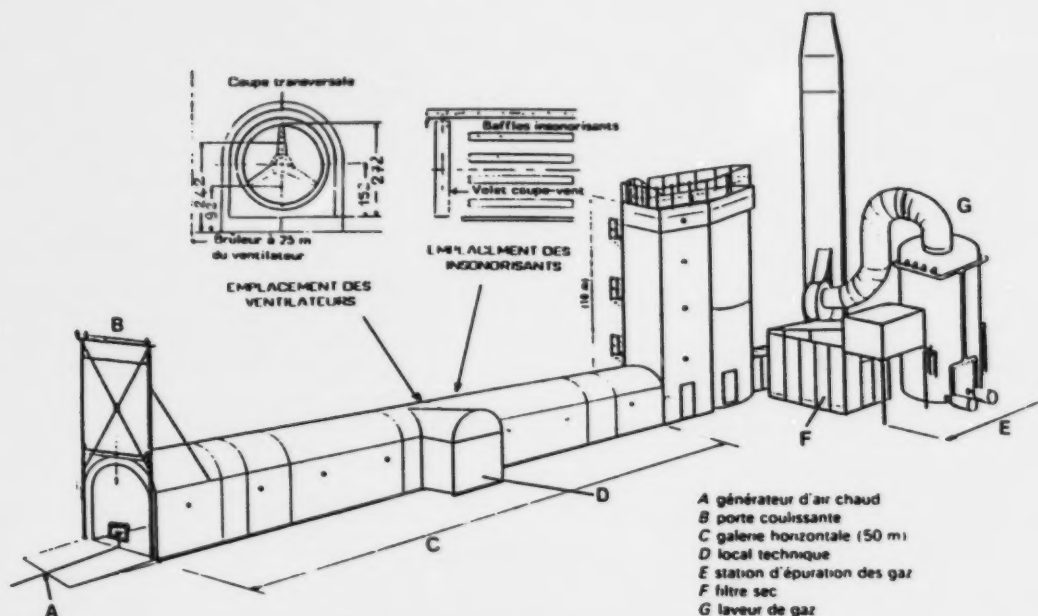


Fig. 1. — Schéma de la galerie incendie du CERCHAR

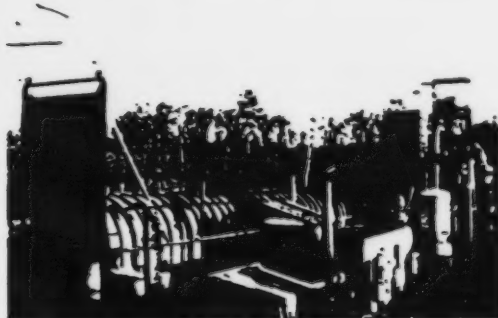


Fig. 2. — Vue de la galerie incendie du CERCHAR

- des caissons insonorisants disposés en amont et en aval du ventilateur ;
- des équipements de contrôle, de commande et sécurité aérauliques, électriques et mécaniques, dont une partie est regroupée dans un local technique.

2.2.2. Installation du poste de ventilation dans la galerie

Le groupe motoventilateur (figures 3 et 4) est installé à 25 m environ de l'entrée de la partie horizontale de la galerie (cf. figure 1). La virole du ventilateur est reliée par une manchette souple à une contre-virole elle-même scellée dans un mur en maçonnerie solide de la galerie.

Un seul caisson insonorisant, composé de quatre baffles, d'épaisseur 20 cm et espacés de 15 cm environ, est disposé à 1 m du ventilateur en aval aérée ; il est précédé d'un volet coupe-vent à commande manuelle avec son contrôleur d'ouverture.

Le local technique est simulé par la niche latérale de la galerie : un mur monté en parpaings de 10 cm le sépare de l'intérieur de la galerie.

2.2.3. Détection des risques de dysfonctionnement

Des dispositions ont été prises pour que la détérioration des différents éléments des circuits normaux d'alimentation et de commande du ventilateur n'interrompe pas le cours de l'essai avant le dysfonctionnement de l'élément principal qui est le moteur. Cependant, les éléments électriques annexes ont été placés en fonctionnement simulé de façon à permettre l'observation de leur propre comportement.

Il s'agit :

- dans la veine d'air :
 - du disjoncteur principal placé devant le moto-ventilateur,
 - du volet coupe-vent (un nouveau modèle de volets a été comparé au modèle ancien),
 - des arrêts *coup-de-poing* situés devant le ventilateur et entre le ventilateur et les insonorisants,
 - du bouton d'arrêt d'entretien disposé à environ 10 m des insonorisants, en aval aérée,
 - des câbles électriques situés en amont de l'armoire électrique (autour du coffret sur voie) ;
 - des câbles d'alimentation normale du moteur et du frein ;
- dans le local électrique :
 - de différents composants de l'armoire électrique et de l'automate programmable (fusibles, relais magnéto-thermiques).

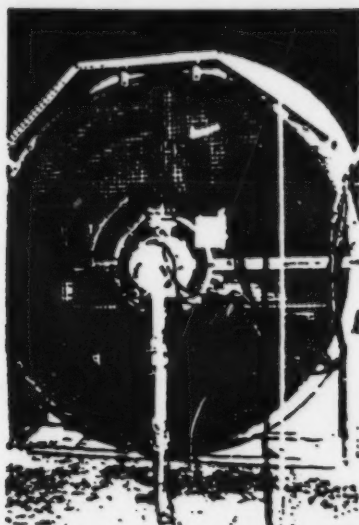


Fig. 3. — Vue du ventilateur

2.2.4. Installation des sprinklers

Parallèlement aux essais d'évaluation du groupe moto-ventilateur, trois sprinklers ont été installés en aval du ventilateur, à 15 m environ des insonorisants, à 2 m de hauteur et espacés de 2 m, afin d'évaluer leur capacité de refroidissement sur une veine ventilée de gaz chauds.

2.2.5. Instrumentation

Une trentaine de mesures de températures ont été effectuées :

- sur le moteur ;
- dans la veine d'air (en amont et en aval du ventilateur et du réseau sprinkler à différents niveaux) ;
- dans les armoires électriques, sur les chemins de câbles, dans l'automate programmable à proximité des insonorisants.

Une sonde de température placée en amont et à 20 cm du moteur (à 1,50 m du sol), dans l'axe du ventilateur, sert de référence pour caractériser la sévérité de l'essai.

Des mesures, aérodynamiques et électriques ont été réalisées avant l'essai en vue de vérifier la bonne concordance des conditions expérimentales et des conditions normales d'utilisation.

2.2.6. Générateur d'air chaud

L'évaluation de la résistance à la chaleur du ventilateur étant réalisée sans recyclage de l'air chaud aspiré, il a été nécessaire d'installer un brûleur capable d'assurer en continu les températures d'essai (jusqu'à 400 °C environ) pour le débit de ventilation (216 000 m³/h).

Un brûleur de puissance réglable entre 3 000 et 15 000 kW a été spécialement conçu à cet effet ; il est disposé à l'entrée de la galerie et comprend :

- un brûleur du type torche à multiples injecteurs et un organe de réglage du débit ;

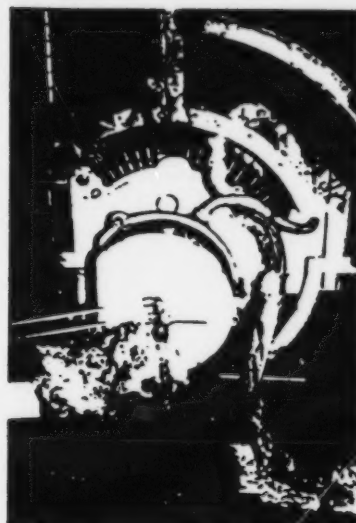


Fig. 4. — Détails du moteur du ventilateur

- un brûleur pilote d'allumage de la torche et son dispositif de contrôle de flamme ;

- un ensemble de sécurité avec vanne automatique sur l'alimentation du brûleur principal ;

- un ensemble réservoir de propane liquide de stockage (8 m³), pompe avec volucompteur.

La figure 5 représente schématiquement le dispositif de génération d'air chaud.

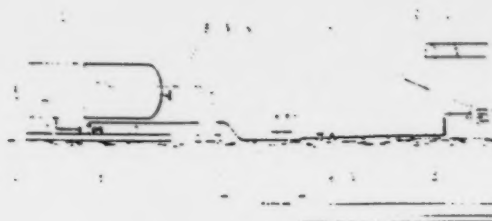
Le débit d'alimentation en propane liquide est ajusté manuellement par un robinet placé à proximité de la torche, à partir de l'indication donnée par un thermomètre numérique relié au point de mesure qui sert de référence (température de l'air aspiré au niveau du moteur) permettant ainsi d'assurer la régulation de température.

Un déflecteur d'air en isolant réfractaire est disposé à proximité du brûleur à 1 m en aval de celui-ci ; il permet de protéger la galerie du rayonnement de la flamme et d'améliorer le brassage des gaz.

Le tableau I donne les puissances du brûleur nécessaires pour obtenir les différents paliers de température moyenne de l'air au niveau de la sonde de référence.

La figure 6 représente le déflecteur à l'entrée de la galerie et la figure 7 le brûleur en action.

TABLEAU I Puissance du brûleur	
P (kW)	Température (°C)
3 250	50
5 660	100
7 590	150
9 900	200
11 600	250
13 000	300
14 500	350
15 500	400
Consommation moyenne 2,27 10 ³ L/min : kW pour le propane liquide	



1. réservoir propane (8 m³)
2. chassis métallique
3. pompe de transfert
4. soupape de décharge
5. ligne de dégazage du compteur
6. volucompteur
7. poste propane alimentation du brûleur pilote
8. vanne de sécurité
9. vanne de réglage de débit
10. brûleur pilote
11. brûleur principal
12. galerie
13. déflecteur d'air

Fig. 5. — Générateur d'air chaud

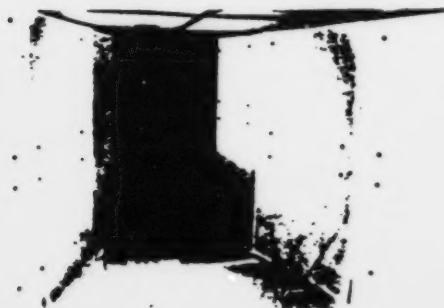


Fig. 6. — Déflecteur d'air chaud

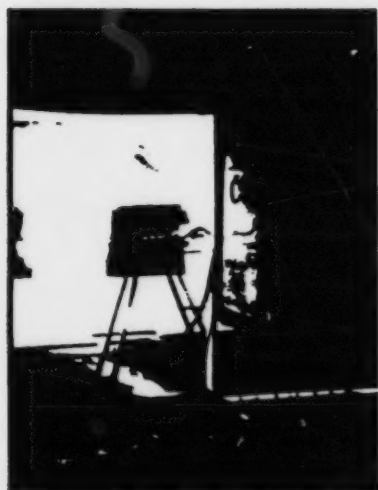


Fig. 7. — Brûleur en action

3. Déroulement des essais et résultats

Deux séries d'essais ont été réalisées, l'une avec un moteur de classe d'isolation B, l'autre avec un moteur de classe H.

3.1. Définition des classes d'isolation des moteurs

Les caractéristiques des bobinages des isolants, les échauffements tolérés en fonction des classes d'isolation sont indiqués dans le *tableau II*, pour une ambiance de température maximale 40 °C (figurent également dans ce tableau les classes E et F pour mémoire).

Dans le cas où la température ambiante dépasse la valeur limite de 40 °C, deux solutions sont possibles :

- réaliser le moteur dans une classe d'isolation supérieure ;
- garder la classe d'isolation, mais en changeant le type de moteur de façon à ce qu'il soit utilisé à puissance réduite.

3.2. Considérations préalables sur les durées probables de fonctionnement à haute température

Des études ont permis de dégager les relations qui régissent les tenues mécaniques et diélectriques des isolants de bobinage de moteur en fonction des températures atteintes et des durées d'action.

Il est apparu que le logarithme du temps nécessaire pour atteindre une valeur particulière de dégradation variait linéairement en fonction de l'inverse de la température absolue à laquelle était soumis le bobinage :

$$\ln t = \frac{K}{T} + Cte$$

Cette relation a été définie pour les deux classes B et H. Elle est donnée sur la *figure 8* et caractérise la durée de vie des isolants mis en œuvre.

Généralement, toute surchauffe de 8 à 12 °C aura pour effet de doubler la vitesse de vieillissement.

La durée normale de fonctionnement (60 000 h) d'un ventilateur avec moteur de classe B correspond à une température ambiante de 40 °C.

L'utilisation des ventilateurs pour assurer le désenfumage correspond à des conditions anormales de fonctionnement des moteurs (durée limitée à un petit nombre d'heures).

L'extrapolation de la relation précédente pour les moteurs des classes B et H aux valeurs élevées de température laisse espérer un fonctionnement d'une dizaine d'heures à 280 °C pour le moteur de classe B et à 400 °C pour les moteurs de classe H (cf. *figure 3*).

3.3 Description des essais et résultats

Les essais ont été réalisés par paliers correspondant à des températures croissantes à l'aspiration du ventilateur et poursuivis jusqu'à détérioration des différents éléments et notamment des moteurs électriques.

TABLEAU II					
Classes d'isolation des moteurs					
Classe d'isolation	Echauffement maximal par mesure de résistance (°C)	Température limite du bobinage (échauffement - ambiance) (°C)	Qualité de l'émail des fils de bobinage	Nature des isolants solides	Base du vernis d'imprégnation
E	75	115	Formvar	Stratifiés coton Stratifiés papier Tissus verre imprégnés	Résine époxyde
B	80	120	Téréphtalique	Tissus verre imprégnés Complexes à base téréphtalate de polyéthylène	Résine époxyde
F	100	140	Téréphtalique	Fibres synthétiques haute température (isolants souples et stratifiés)	Résine époxyde
H	125	165	Polyamide	Fibres synthétiques haute température (isolants souples et stratifiés)	Résine silicone modifiée

Les dispositifs détériorés lors d'un essai n'ont pas été remis en état pour l'essai suivant. A la fin des essais, étaient toujours opérationnels :

- le moteur de classe H,
- les insonorisants.

Les dispositifs électriques et électroniques du local technique avaient été supprimés à l'issue des essais du moteur de classe B, mais ils étaient encore en état de fonctionnement.

Les figures 9 et 10 schématisent la chronologie des essais du moteur de classe B avec indication des disfonctionnements observés.

La figure 11 représente l'essai du moteur de classe H.

3.4. Examen détaillé du comportement des matériels

3.4.1. Moteurs

Le moteur de classe B a fonctionné pendant environ 1 h à 250 °C et le moteur de classe H pendant 1 h à 350 °C, et cela bien que les conditions des essais réalisés soient beaucoup plus pénalisantes que celles des essais de laboratoire (montée plus rapide au seuil des températures visées, énergie thermique absorbée par le moteur plus forte).

Par ailleurs, un constat effectué chez le fabricant des moteurs a montré :

- pour le moteur de classe B : une mise à la masse des enroulements sur les trois phases entraînant un disfonctionnement irréversible du moteur ; en revanche, toute la partie mécanique (roulements, freins) est restée en bon état ;

- pour le moteur de classe H : les parties électriques et mécaniques sont en bon état malgré une altération marquée des bobinages, des enroulements et du disque du frein (bleuissement) ; il est à noter que, pour cet essai, le moteur avait été protégé par une graisse

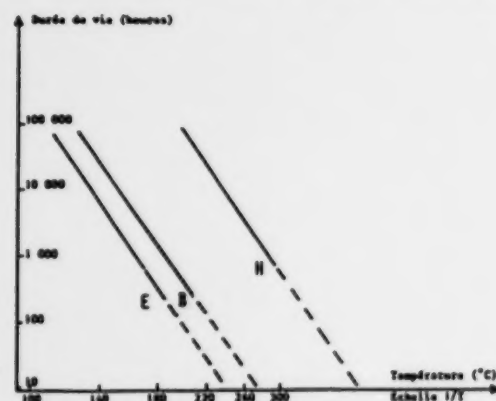


Fig. 8. — Courbes de durée de vie des isolants de bobinage pour les classes d'isolation E, B et H

spéciale haute température. Le moteur est resté opérationnel.

3.4.2. Autres équipements

• Câble standard

Les essais ont montré que le câble standard supporte bien la température (2 h à 120 °C) lorsqu'il est disposé en partie droite, par exemple dans des chemins de câbles.

En revanche, dès qu'il présente un coude ou un passage non protégé en veine, il devient alors très sensible, surtout lorsqu'il subit une contrainte mécanique. C'est cette situation qui a conduit au défaut D1 (voir figure 9, essai 1).

Une attention particulière est à apporter à la tenue thermique des colliers de serrage et aux câbles de liaison moteur-frein qui se sont montrés particulièrement fragiles.

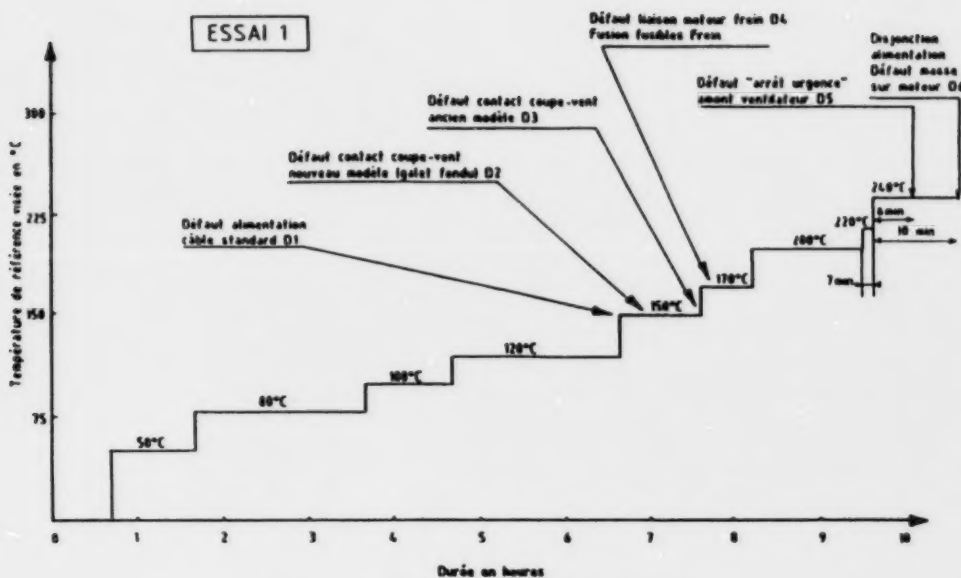


Fig. 9. — Moteur de classe B : chronologie des incidents lors de l'essai 1

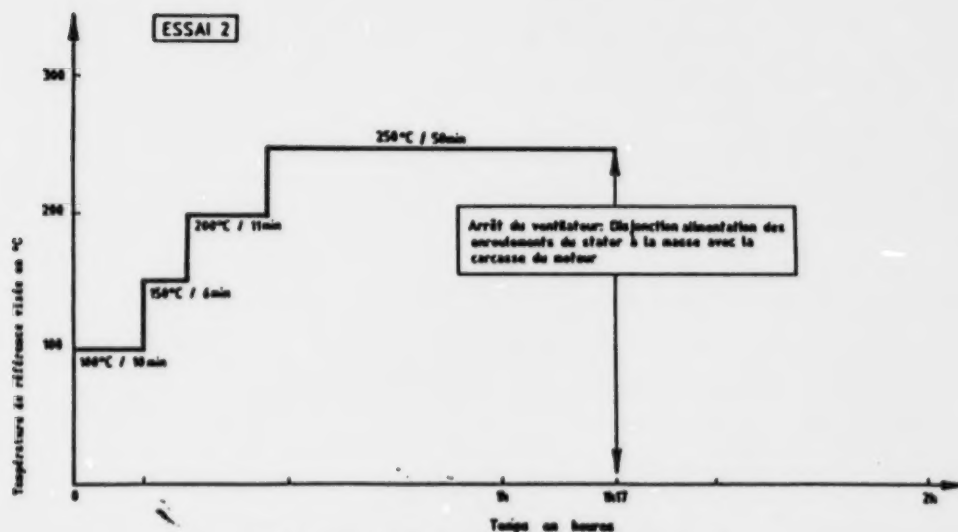


Fig. 10. — Moteur de classe B : chronologie des incidents lors de l'essai 2

Compte tenu du gradient important de température de la veine de gaz en cas d'incendie, il y aura lieu de positionner les câbles plutôt en partie basse.

• *Contact de contrôle coupe-vent*

Le nouveau modèle a cédé à 150 °C après 15 min et l'ancien modèle à 150 °C après 52 min (galette de contact et bloc fondus ; mécanisme partiellement fondu).

Ces deux dispositifs ne semblent pas pouvoir tenir avec une bonne probabilité à une température de 150 °C.

• *Bouton arrêt entretien*

Pour une température voisine de 220 °C, le bouton d'arrêt entretien peut provoquer, par ouverture, l'arrêt du ventilateur. On a pu remarquer la fusion des cabochons des voyants, les boutons de fixation détruits, enfin, le boîtier légèrement cloqué avec le mécanisme hors service.

• *Bouton arrêt coup-de-poing*

Les boîtiers métalliques ne sont pas déformés, les boutons de réarmement et les presse-étoupes sont

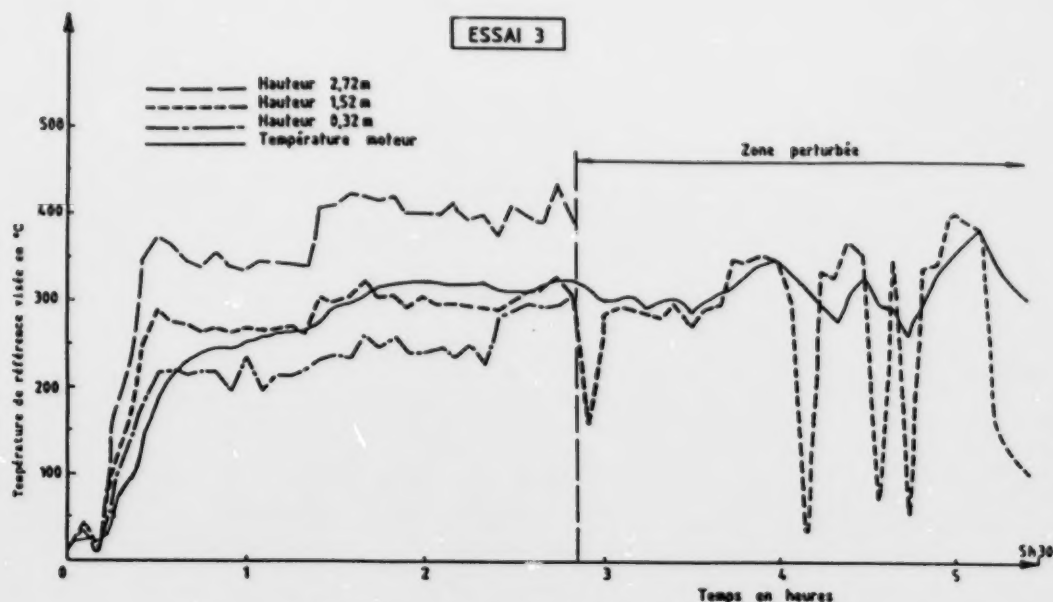


Fig. 11. — Moteur de classe H : évolution des températures en amont du ventilateur

fondus. De plus, les mécanismes se sont bloqués, ce qui aurait entraîné l'arrêt du ventilateur.

• Coffret différentiel sur voie

Le coffret est resté opérationnel bien que le couvercle en PMMA ait entièrement fondu.

• Frein moteur

Différents points faibles sont apparus :

- bouchons en plastique sur chaque flasque côté frein et côté hélice fondus ;
- tuyaux de graissage en polyéthylène détériorés.

La conception de la plaque à bornes est à revoir (on a pu constater à l'intérieur de celle-ci la formation d'une couche de matière carbonisée, des courts-circuits entre câbles d'alimentation moteur et frein, un manque d'étanchéité au niveau des presse-étoupes).

• Armoire de commande

Aucune altération n'a été constatée, bien que la température atteinte dans la niche ait approché 100 °C à la fin des essais.

• Automate programmable

Dans les mêmes conditions, un automate a assuré sa fonction tout au long des essais.

• Porte de la niche

Le joint a subi une déformation sous l'effet de la chaleur, d'où une étanchéité aléatoire.

• Plots, manchette souple, hélice

On a noté une altération des plots antivibratiles pouvant déséquilibrer le groupe motoventilateur.

La manchette souple en toile plastifiée s'est entière-

ment consumée sans pour autant entraîner une modification du fonctionnement aérodynamique du ventilateur.

A haute température (350 °C), on a noté des bruits suspects de frottement de l'hélice qui ont précédé la disjonction et l'arrêt du ventilateur (bruits qui ont disparu après retour à la température ambiante ; une marche pendant 1 h et à 350 °C a pu se faire par la suite sans bruits particuliers).

3.4.3. Commentaires sur les essais sprinklers

Les paramètres étudiés durant ces essais sont, d'une part, la pression d'alimentation de l'eau dans les têtes d'arrosage et, d'autre part, le nombre de têtes en fonctionnement.

Les postes de ventilation n'étant pas normalement protégés par ce système, l'optimisation de la densité d'implantation n'a pas été réalisée.

Les remarques suivantes peuvent être faites :

- l'alimentation sous 2,5 bar (pression moyenne actuelle des postes d'eau situés dans la station de ventilation) est très peu efficace ; on refroidit la veine d'air de 10 °C avec une tête d'arrosage, de 20 °C avec deux ou trois têtes d'arrosage ;

- l'alimentation sous 8 bar permet d'abaisser la température de 40 à 50 °C.

La figure 12 représente les sprinklers en action sous 2,5 bar et la figure 13 les mêmes sprinklers sous 8 bar. On note, dans ce dernier cas, la formation d'un brouillard plus efficace pour les échanges de chaleur.

4. Conclusions

La méthode originale choisie a consisté à soumettre aux essais un ensemble d'éléments rendus interdépendants, soit de manière aérodynamique, soit de manière électrique.

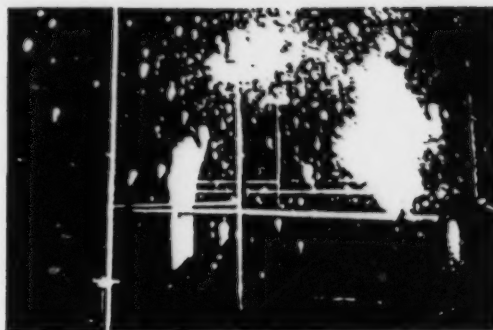


Fig. 12. — Effet sprinkler sous 2.5 bar

Cette méthode s'oppose en partie aux méthodes réglementaires qui consistent à tester des éléments séparés, de manière statique et non dépendante d'un fonctionnement d'ensemble. Une question se pose alors pour la fiabilité d'un assemblage de ces éléments : comment peut-on être sûr qu'il n'y aura aucune interaction prévisible ou aléatoire de deux ou plusieurs d'entre eux ?

Il apparaît, en fait, qu'une chaîne fonctionnelle (tableau électrique, câbles, moteurs) peut présenter des risques supplémentaires du fait que chaque élément ne se comporte pas seulement en fonction de ses propres caractéristiques, mais que l'organisation du système lui confère des propriétés nouvelles et que cette synergie définit le comportement de l'ensemble.

Les résultats de ces essais, effectués au CERCHAR, sont nombreux et riches d'enseignements et concernent les deux aspects suivants.

4.1. Tenue au feu des sous-éléments et de l'ensemble global

D'une part, l'ensemble des éléments constitutifs d'un poste de ventilation type métro, conçu uniquement pour l'amélioration des conditions de confort et d'hygiène à la température ambiante, peut permettre l'extraction de fumées chaudes jusqu'à une température de 120 °C, pendant 2 h.

D'autre part, alors que le moteur était supposé être l'élément faible de la chaîne — ce qui a conduit à des essais prudents et longs — on a pu montrer, sans ambiguïté, que le moteur de classe B assurait sa fonction jusqu'à une température de 250 °C pendant 1 h, et qu'un moteur de classe H restait opérationnel jusqu'à 350 °C pendant plus d'une heure malgré la sévérité plus grande de l'essai par rapport aux essais normalisés.

Pour atteindre un bon niveau de sécurité — dans des conditions économiques raisonnables — fixé à 250 °C pendant 1 h à partir des possibilités du moteur, il convient de modifier tous les éléments faibles que



Fig. 13. — Effet sprinkler sous 8 bar

les essais ont permis de définir, permettant aussi du même coup de préciser l'investissement minimal nécessaire.

4.2. Connaissance des phénomènes en cas d'incendie

Les considérations suivantes, que les essais en galerie expérimentale ont permis de préciser sur plusieurs points, orientent la réflexion sur les possibilités d'utilisation des ventilateurs de confort pour assurer le désenfumage en cas d'incendie.

Les conditions envisageables de fonctionnement du matériel, après les modifications mineures définies précédemment, restent sûres dans le cas d'une source de chaleur accidentelle d'une puissance de 10 MW (15 L d'essence par minute) à proximité immédiate du poste de ventilation : compte tenu de la faible probabilité que l'incendie se produise au droit exact d'un poste et de l'importance des échanges thermiques aux parois d'une galerie en régime transitoire, ces conditions restent bien entendu valables dans la grande majorité des cas avec des sources nettement plus puissantes.

Il s'établit très rapidement en galerie un fort gradient thermique vertical en aval d'un incendie : on note par exemple à 25 m du générateur de fumées et pour une température de référence de 400 °C une différence de 200 °C entre le haut et le bas de la veine. Cette circonstance permet d'optimiser le positionnement de certains équipements (câbles, bouton de sécurité, etc.). En revanche, la température de la veine est homogénéisée en aval du ventilateur.

Enfin, la mise en place de sprinklers peut apporter au dispositif de sécurité un appoint dont l'intérêt varie cependant beaucoup avec la pression d'eau disponible dans la station de ventilation. Sans optimisation particulière de leur fonctionnement, nous avons obtenu dans les conditions d'essais un abaissement de plusieurs dizaines de degrés de la température moyenne en veine, mais seulement avec une pression d'alimentation de 8 bar.

ETUDE DES NICHES PRESSURISABLES
CONVENTION CECA N° 7258-02/03/104

- SYNOPSIS -

1. INTRODUCTION

En cas d'incendie dans les chantiers souterrains, les plans d'évacuation prévoient de rassembler le personnel en quelques points privilégiés par rapport à l'aérage, puis de l'évacuer par des itinéraires choisis, vers la surface.

Dans le cas où les itinéraires d'évacuation ne pourraient être empruntés par suite de l'envahissement des galeries par des gaz toxiques la procédure est de gagner des lieux de refuge mis en légère surpression par admission d'air comprimé et que l'on appelle pour cette raison "niche pressurisable".

Les personnes évacuées sont généralement équipées de leur APEVA et gagnent les abris, soit pour y réaliser l'échange de leurs appareils, soit pour y attendre d'autres secours et recevoir des instructions. Pour le personnel rassemblé dans ces niches le risque essentiel concerne la chaleur et les gaz toxiques.

Il est nécessaire que la chaleur des fumées d'incendie soit arrêtée le plus efficacement et le plus longtemps possible : il faut également éviter la pollution des abris pendant et après l'arrivée du personnel.

2. PROGRAMME DE RECHERCHES

La recherche entreprise au CERCHAR avec l'aide financière de la CECA a pour objet de fixer les limites dans lesquelles les mineurs pourront être protégés, non seulement contre une atmosphère toxique et asphyxiante, mais aussi contre une température excessive des fumées. Elle a également permis de rechercher des matériaux souples pour la confection de rideaux dont la nature, la structure et la mise en oeuvre permettent d'assurer l'action coupe-feu et d'isolation thermique ainsi que d'étanchéité aux gaz pour une protection efficace et durable contre les effets de l'incendie.

Deux conceptions différentes de niches ont été étudiées dans le cadre de cette convention :

- une niche composée d'éléments de tubing et disposée à même la galerie,
- une niche creusée sur le côté de la galerie et fermée par un rideau qui assure la protection contre le flux thermique et les gaz toxiques.

La recherche a été effectuée dans la galerie incendie du CERCHAR à Verneuil-en-Halatte.

Dans la portion horizontale longue d'une cinquantaine de mètres a été aménagée vers le milieu une niche de "type latérale" ; quelques mètres devant celle-ci ont été disposés les éléments de tubing pour simuler le deuxième type de niche.

Les essais ont consisté à soumettre chaque type de niches successivement aux fumées chaudes d'un foyer d'incendie dont on a pu régler à notre guise la puissance calorifique.

Un brûleur à gaz capable d'assurer en continu les températures visées au débit du ventilateur assurant l'aérage de la galerie, a été mis au point. Ce brûleur de puissance réglable entre 1 000 et 10 000 kW a été disposé à l'entrée de la galerie.

Les facteurs importants suivants ont été pris en compte :

- la ventilation naturelle qui tend à s'établir entre la galerie et la niche choisie (problèmes de pressurisation),
- les échanges thermiques entre les fumées chaudes de la galerie et l'atmosphère à l'intérieur de l'abri,
- la résistance à la chaleur des éléments souples de fermeture (rideaux).

Après évaluation des comportements et caractéristiques de ces niches dans leur conception actuelle nous avons cherché à optimiser leurs conditions d'utilisation en cherchant :

- à refroidir les fumées chaudes dans la galerie en amont de la niche par des sprinklers,
- à refroidir les éléments de tubing par arrosage,
- à refroidir les rideaux par arrosage,
- à refroidir l'air injecté dans la niche,
- à isoler thermiquement la niche type tubing.

3. SYNTHÈSE DES RESULTATS

Une recherche bibliographique nous a permis de montrer que le niveau moyen de température que l'on pouvait atteindre à quelques centaines de mètres d'un foyer d'incendie était de l'ordre de 100 à 200°C. Ces valeurs ont été reproduites expérimentalement dans nos installations.

Pour réaliser les paliers de température la puissance du brûleur a été réglée respectivement à 1.1 MW (100°C au niveau de la niche) et 2.5 MW (200°C au niveau de la niche).

3.1 Répartition des températures dans la galerie

Les courbes de températures-temps obtenues à partir d'une série d'essais pour plusieurs puissances de brûleur nous ont permis d'évaluer la distribution des températures dans la galerie en amont, au droit et en aval des niches à différentes hauteurs.

Nous avons constaté, pendant les durées d'essais mises en jeu, la formation de deux couches de gaz dans la zone où était disposée la niche :

- une couche de gaz très chaud partant de la voûte pour descendre jusqu'à environ 2.5 m au-dessus du sol,

- une couche de gaz plus froid s'étendant du niveau du sol jusqu'à 1.7 m de hauteur,

et entre ces deux couches, on observe un "saut thermique" important de l'ordre de 300 à 400°C.

3.2 Comportement de la niche "type tubing"

En premier lieu nous avons expérimenté l'étanchéité aux gaz et défini la quantité d'air à injecter dans la niche pour en assurer la purge ; un diagramme de ventilation fonction du volume à purger et du degré de pureté recherchée a été mis au point. Les courbes permettent d'établir la quantité d'air à injecter dans une niche polluée avant d'y pénétrer : ce volume d'air a été estimé à au moins 5 fois le volume de la niche. Un débit d'air de 300 Nm³/h permet de maintenir la niche en légère surpression (15 à 25 pascals) lorsque la température des gaz dans la galerie est de 200°C.

En second lieu nous avons déterminé l'évolution des températures dans la niche avec et sans dispositif de refroidissement en fonction de celle dans la galerie.

Les principaux résultats suivants ont été obtenus :

Pour une température de 100°C fixée en palier dans la galerie, la température mesurée dans la niche atteint rapidement une valeur de 80-85°C.

Le refroidissement des parois de la niche par ruissellement d'eau permet de ramener la température à 60°C pour un débit d'eau de 2.5 m³/h et 40°C pour un débit d'eau de 6 m³/h.

Lorsqu'on porte le niveau de température dans la galerie à 160°C, la température à l'intérieur de la niche arrosée dépasse la limite de tolérance humaine et atteint 65°C.

Lorsqu'on porte le niveau de température dans la galerie à 200°C, la température à l'intérieur de la niche arrosée se stabilise autour de 100-110°C.

Les essais de refroidissement de la veine d'air chaud, en amont de la niche, par sprinkler, ont montré que l'on pouvait gagner entre 30°C et 50°C dans la galerie selon que le sprinkler se trouve à 3 m ou à 1.7 m de hauteur.

Enfin nous avons testé la résistance thermique de l'abri lui-même et de ses éléments constitutifs (éléments de fermeture souple et canalisation d'admission d'air).

Nous avons montré que les rideaux à base de bande de convoyeur ou d'éléments de ventube, souvent utilisés pour la confection des portes souples, étaient à proscrire ; différents tissus souples à base de verre enduit de silicone ont donné de très bons résultats. Par ailleurs, la disposition des canalisations d'air à l'intérieur de la galerie peut poser des problèmes (solicitation thermique trop élevée pouvant entraîner leur ruine et température de l'air comprimé injecté dans la niche trop importante).

3.3 Comportement de la niche "type latérale"

Le débit de l'air comprimé ($300 \text{ Nm}^3/\text{h}$) injecté dans cette niche a permis de la maintenir en très légère surpression (5 à 10 pascals). Les analyses des gaz effectuées ont montré que dans ces conditions le volume de la niche reste purgé et ce quel que soit le niveau de température dans la galerie.

Trois rideaux souples différents à base de tissus de verre ont été expérimentés ; ils sont enduits soit d'hypalon, soit de résine silicone. Les essais ont montré que cinq matériaux sont dotés d'une excellente résistance au feu.

Les mesures de température dans la niche ont donné les résultats suivants :

- pour une température de 200°C fixée en palier au niveau de la face extérieure du rideau arrosée la température mesurée dans la niche n'a pas dépassé 25 à 35°C après plusieurs dizaines de minutes d'essai,
- la vitesse moyenne de montée de température dans la niche est de $0.15^\circ\text{C}/\text{min}$ lorsque le rideau est refroidi ; elle passe à $4^\circ\text{C}/\text{min}$ lorsqu'on arrête l'arrosage du rideau.

Quel que soit le niveau de température au droit du rideau dans la galerie (valeur comprise entre 70°C et 220°C) le niveau moyen de température dans la niche ne dépasse jamais la limite de tolérance humaine fixée à 60°C .

4. CONCLUSION

Cette recherche a permis d'obtenir des renseignements importants sur le comportement de deux types de niches pressurisables de conception très différente.

Leur conception et utilisation est à définir cas par cas et fonction de leur destination : si la niche doit constituer principalement un lieu de regroupement ou de relais aux APEVA l'aspect étanchéité aux gaz toxiques est à privilégier ; si elle doit servir de refuge pendant la durée d'un incendie, la protection contre les gaz chauds (impacts thermique et toxique) devient l'élément prépondérant.

- L'étude du refroidissement :
- de la veine d'air chaud,
 - du rideau par arrosage dans le cas de la niche latérale,
 - de l'air comprimé,

a montré que l'on pouvait espérer, sans optimisation, obtenir une baisse notable des températures, ce qui est un résultat très encourageant et mériterait une étude spécifique plus poussée. La mise en place d'un réseau d'arrosage constituerait en effet une solution simple pour permettre l'utilisation des niches à proximité directe d'un incendie.

COMPORTEMENT DANS UN INCENDIE DE MATERIAUX FORMOPHENOLIQUES

UTILISES DANS LES TRAVAUX SOUTERRAINS

CONVENTION CECA n° 7258-02/03/121

- SYNOPSIS -1. INTRODUCTION

L'évolution des techniques minières et la mise à la disposition des mineurs de nouveaux matériaux polymériques ont eu pour effet d'augmenter leur utilisation dans les travaux souterrains. Ces produits facilitent le travail des mineurs, améliorent la sécurité mais introduisent simultanément des risques nouveaux qu'il importe d'étudier.

Il s'agit ici d'étudier le comportement de certaine classe, les formophénoliques, de produits polymériques pris dans un incendie.

2. OBJECTIF

Les essais de réaction au feu auxquels les matériaux polymériques descendus au fond ont dû satisfaire s'attachent à caractériser leur inaptitude à l'inflammation et à la propagation du feu. Par contre ils n'ont pas toujours fait l'objet d'études systématiques sur les conséquences sur l'atmosphère de la mine que pourraient avoir les produits issus des phénomènes de combustion et de pyrolyse de ces matériaux.

En fait, au cours de ce type d'étude, la pertinence des résultats obtenus dépend de l'aptitude du matériau et de la source de chaleur à refléter les événements transitoires et dynamiques d'un incendie. Ceci suppose des essais proches des situations réelles et c'est la raison pour laquelle l'étude a été menée dans la galerie incendie du CERCHAR.

Le produit étudié est une mousse formophénolique utilisée, entre autres, en gunitage de galerie. Ce travail comporte quatre volets :

- une étude de caractérisation de la mousse et de ses composants.
- une étude du comportement de fûts de résine stockés et pris dans un incendie.
- une étude du comportement de la mousse posée dans une galerie et prise dans un incendie.
- une comparaison des comportements de deux mousses différentes : formophénolique et urée-formol.

3. SYNTHESE DES RESULTATS3.1. Caractérisation des produits

La caractérisation a été faite sur la mousse et ses composants : résine de base et catalyseur. Il s'agit d'analyses élémentaires, de spectrométrie de masse, d'analyses thermiques différentielles et gravimétriques.

Les résultats obtenus montrent que sur le plan de la toxicité des produits de pyrolyse et de combustion, le risque potentiel est assez faible compte tenu du peu d'azote présent dans ces produits.

Les analyses ATD-ATG font apparaître pour la mousse un pic exothermique vers 230°C. La résine présente un petit pic exothermique à 450°C tandis que le catalyseur est inerte.

3.2. Essais en grandeur

Les essais ont été réalisés dans la galerie incendie du CERCHAR. Elle se compose d'une partie horizontale de 10 m² de section et 50 m de longueur, d'une partie verticale de 6 m² de section et 10 m de hauteur et d'un système d'épuration et d'extraction des fumées.

Les produits sont soumis à l'incendie d'un bûcher de bois de 300 kg.

De nombreux capteurs sont installés autour du foyer et dans la tour au point dit de mélange. En ce point assez éloigné du foyer on admet que les fumées sont homogènes et donc que les prélèvements et les mesures faites sont représentatives de l'ensemble des phénomènes. Cette instrumentation permet donc de réaliser des bilans tandis que l'instrumentation locale est destinée à la description du déroulement de l'incendie (aspect cinétique).

Un essai de référence réalisé avec un bûcher de 300 kg mais en l'absence de tout produit polymérique permet, par différence, d'estimer l'impact propre aux produits étudiés.

3.3. Comportement de fûts de résine vis-à-vis d'un incendie

La résine de base servant à fabriquer la mousse est conditionnée en fûts métalliques. Ils sont stockés au fond en attendant leur utilisation.

Trois bidons de 30 kg de résine chacun ont été disposés à proximité d'un bûcher de 300 kg.

L'observation du comportement des fûts au cours de l'incendie du bûcher, les mesures et les analyses peuvent se résumer de la façon suivante :

sous l'effet de l'incendie, les fûts se sont déformés, ont basculé puis le bouchon a sauté. La résine a été projetée sur une distance de quelques mètres et s'est répandue au sol. Elle ne s'est pas enflammée et n'a pas propagé l'incendie, sa température ne semble pas avoir atteint celle du pic exothermique. Il apparaît d'abondantes fumées blanches (vapeur d'eau) et peu de produits toxiques (fréon).

3.4. Comportement vis-à-vis de l'incendie de mousse utilisée en gunitage de galerie

Environ 700 kg de mousse ont été projetés sur une surface de 100 m² de galerie (soit une longueur un peu supérieure à 10 m) et comme pour l'essai précédent on a enflammé un bûcher de 300 kg placé sous le revêtement.

Sous l'effet de l'incendie on a pu observer le bon comportement de la mousse formophénolique puisque même au plus près du bûcher elle est restée en place et n'a été calcinée qu'en surface.

La mousse n'a pas propagé l'incendie, sa calcination n'a duré que le temps de la combustion du bûcher.

En ce qui concerne l'impact toxique des gaz produits, on observe qu'il est caractérisé essentiellement par un dégagement de CO, composé classiquement rencontré dans les incendies mettant en oeuvre des matériaux organiques.

3.5. Comparaison du comportement entre une mousse formophénolique et une mousse urée-formol

Dans le cadre d'un précédent contrat une mousse de type urée-formol avait été soumise à l'incendie d'un bûcher dans des conditions assez voisines de celles des expériences qui viennent d'être présentées.

Plutôt utilisée en remplissage de cavités ou fissures cette mousse urée-formol avait été expérimentée dans la galerie incendie sous forme de revêtement.

Il était donc intéressant de comparer le comportement des deux produits vis-à-vis d'un incendie de bûcher.

Les résultats montrent qu'après l'incendie, la mousse formophénolique est toujours en place et conserve pratiquement ses propriétés même lorsque sa surface est carbonisée. La mousse urée-formol a presque totalement brûlé.

Sur le plan de la toxicité, la mousse urée-formol présente un risque plus aigu (à cause de la production d'acide cyanhydrique et d'oxydes d'azote) que la mousse formophénolique.

4. CONCLUSIONS

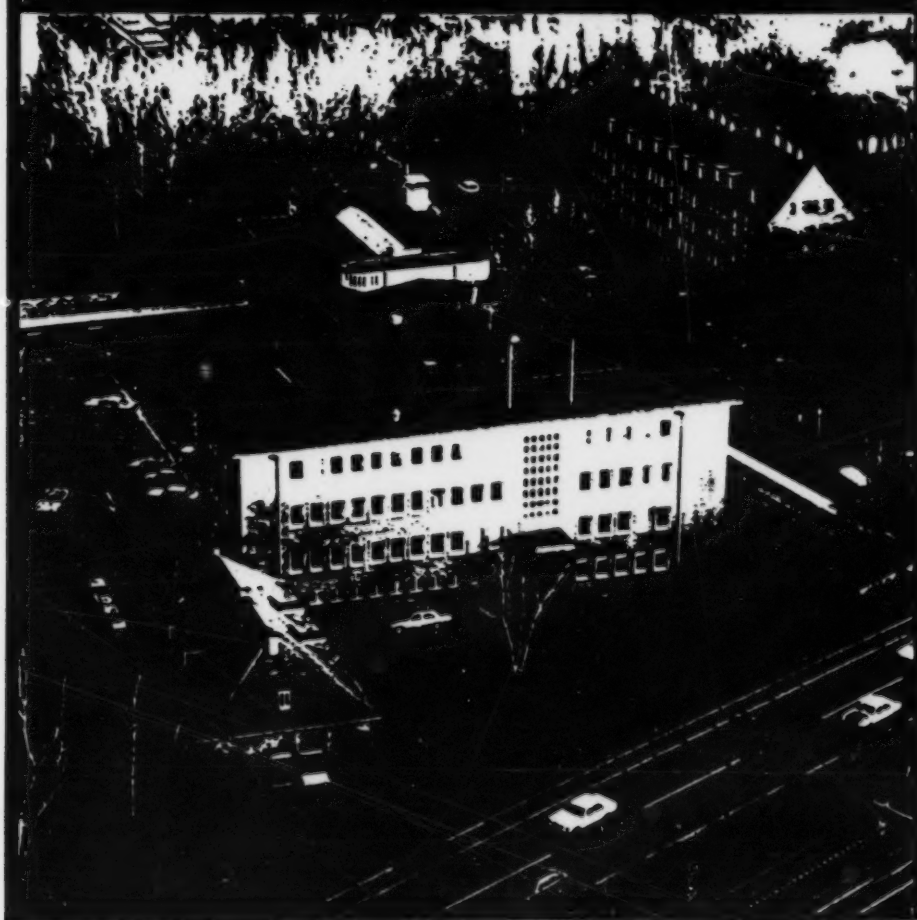
Les résultats présentés ci-dessus correspondent au scénario d'un incendie bien particulier, ils n'ont pas valeur universelle. Ils permettent cependant de conclure à un bon comportement de la mousse formophénolique prise dans un incendie et au peu de risque présenté par le stockage des fûts de résine de base. Il n'en est pas de même pour la mousse urée-formol qui brûle et dégage des produits toxiques azotés.

HAUPTSTELLE MINE RESCUE CENTRE

Essen, Germany



Hauptstelle
für das
Grubenrettungs-
wesen
Essen



Bergbau-Forschung GmbH Steinkohlenbergbauverein	A-GR	HAUPTSTELLE FÜR DAS GRUBENRETTUNGSWESEN, ESSEN (H GRW E)	Organisationschema Stand: 02. Nov. 1988

Leiter: Stellvertretung: Sekretariat:	K o c k Both Fr. Rummel
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3	Prüfung und Entwicklung FAL: Wagner
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2	Brandschutz unter und über Tage FAL: Both
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1	Rettungstechnik und Ausbildung FAL: Funkemeyer
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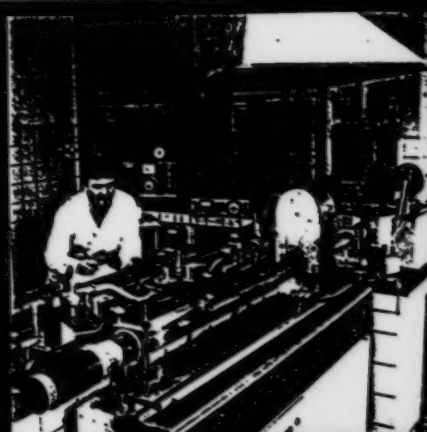
- | | | |
|---|--|--|
| <p>11 Rettungstechnik, Grubenwehren
Einsatz und Bereitschaftsdienst
FGL Funkemeyer
Knoke +, Kaminski, V.</p> <p>12 Selbstrettungstechnik,
Einsatzgeräte
FGL Langer +
Herforth +, Nies +</p> <p>13 Gerätestation, Lehrgangsbetrieb,
Bereitschaftslager
FGL Jansing
Hilbig +, Beitz, Malbach,</p> | <p>21 Brandschutz unter Tage
FGL Hein +
Linberg +, Hoischen, Uhlenbrock</p> <p>22 Brand- und Atemschutz
über Tage,
Gasschutzwehren
FGL Both
Dortmann +, Werner +</p> | <p>31 Atemschutz- und Feuerlöschgeräte
FGL Wagner
Biniok +</p> <p>32 Prüflaboratorien
FGL Kaminski, R. +
Wischerhoff +, Kratz, Möllney</p> <p>33 Untersuchungs- und Entwicklungs-
vorhaben
FGL Bresser</p> |
|---|--|--|

Einsatz und Bereitschaftsdienst Organisation: Funkemeyer	(Both), Bresser, Funkemeyer, Hein, (Kock), Langer, Dortmann, Hoischen, Kaminski, V., Knoke, Linberg, Nies, Uhlenbrock () = kein Grubenwehrmitglied ----- Beitz, Hilbig, Jansing, Kratz, Malbach, Werner, Wischerhoff
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Ausbildung Organisation: Funkemeyer	Both Bresser Dortmann Funkemeyer Hein Herforth	Hoischen Hilbig Jansing Kaminski, V. Knoke Kock	Langer Linberg Nies Uhlenbrock Werner
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Innendienst, Ausschüsse, Verwaltungsaufgaben Organisation: Neuroth	Fr. Koenen, Fr. Nickel Weber, Fr. Ziemer Gödde, Jenter, Steinhoff Bertram, Geis, Wilmes Fr. Paschinski, Vinke
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FAL = Fachabteilungsleiter
+ = stv. Fachabteilungsleiter
FGL = Fachgruppenleiter
+ = stv. Fachgruppenleiter



Kunststoff-Prüfanlage
Prüfanlage für Sauerstoffselbstretter

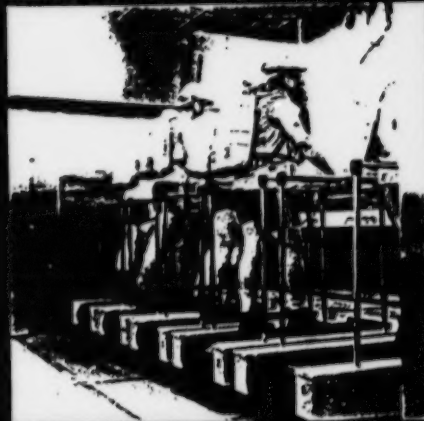


Vollmaske im Flammentest



picture, above:
left: Plastics testing set-up
right: Full-face mask in flame test
picture, below: Test rig for oxygen self rescuers

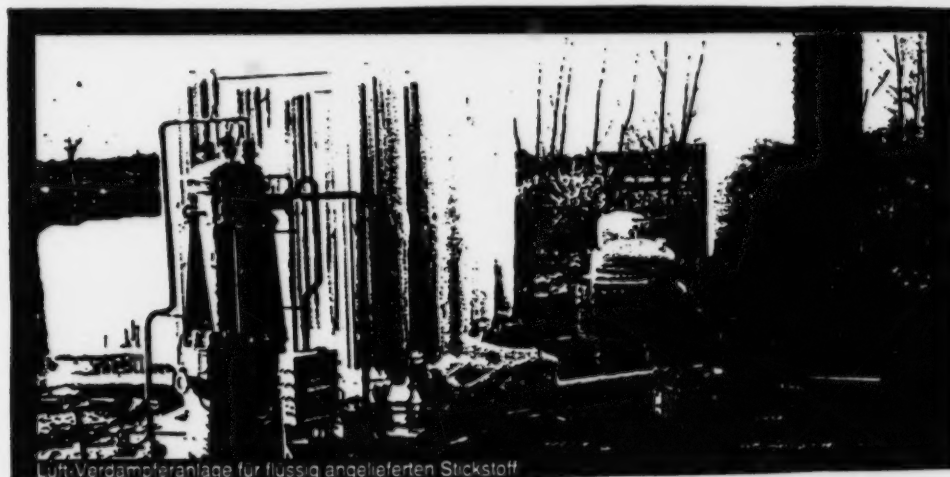
Üben in der Klima-Prüfanlage



Loschübung



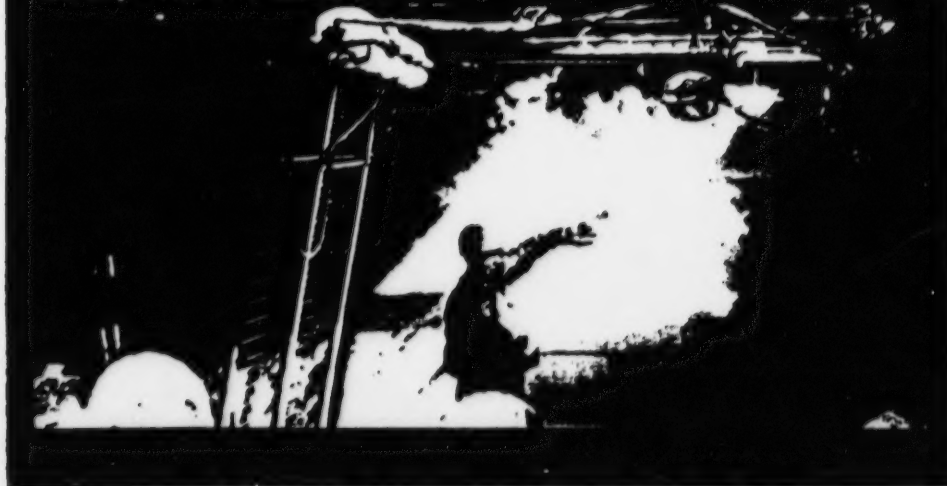
left: Exercise in the climate chamber
right: fire fighting exercise



Luft-Verdampferanlage für flüssig angelieferten Stickstoff

picture, above: Evaporation unit for
liquid nitrogen
picture, below: Training in gas fire fighting

Ausbildung im Löschen von Gasbränden



General terms and conditions of trade for supplies and services

(Note: This translation is intended to facilitate the comprehension of the original German version.
Only the German version is binding.)

I. General

1. Contracts are concluded exclusively according to our terms and conditions. They are recognised at the latest on acceptance of the goods or services supplied. Differing terms and conditions of the purchaser or orderer which we do not recognise in writing are not binding, even if we do not object specifically to these.
2. Our general terms and conditions of trade for supplies and services apply only to the commercial and public sector as defined in § 24 AGB-Gesetz (German Unfair Contracts Act).
3. Subsidiary agreements, assurances and all other statements are only binding when confirmed expressly in writing. The same applies to an alteration of or supplement to these terms and conditions.

II. Tenders and Orders

1. Our tenders are subject to change without notice.
2. The contract becomes effective only on confirmation or execution of our order.

III. Charges and Prices

1. Purchase prices include the supply ex-factory excluding packaging, unless other agreements have been made. The quantities determined by us are definitive for the rendering of accounts.

Should a general change in prices come into effect between the conclusion of the contract and the date of supply, the price effective on the day of supply will be charged. In the event of a price increase, the purchaser has the right to rescind the contract within 14 days after notification of the price increase.

2. Services are charged according to the rates for our list of services applicable on the date at which the service is supplied, unless a fixed price has been agreed in writing.

Services for which no fixed rates are listed are calculated on a time basis according to our personnel charge rates, unless an all-inclusive price has been agreed. In addition to the personnel charge rates, cash expenses for travel (transportation costs, daily allowances and hotel expenses) as well as other expenditure on materials, are invoiced separately.

3. The statutory turnover tax is not included in the prices, fees or personnel charge rates but is invoiced separately.

IV. Special Conditions for Suppliers

1. Passing of the risk

The risk is passed to the purchaser as soon as the goods leave our factory or store and are handed over to the carrier.

2. Quality details and applied consultation

2.1 Details of percentages, mixing ratios or essential characteristics of our goods are only approximate. While every care is taken before despatch, we reserve the right to allow variations in quality, should this prove unavoidable.

2.2 All consultative advice is given in good faith but is in no way binding. It is the responsibility of the purchaser to test the goods supplied and to comply with processing rules, statutory and official regulations.

3. Right of Ownership

3.1 The goods supplied remain the property of the Company until the purchaser has discharged all business obligations towards us.

3.2 If the purchaser processes, combines or mixes our goods, we are considered as manufacturer and acquire ownership of the newly-created goods. If processed together with other materials, we acquire co-ownership by fractional shares in the ratio of the invoice value of our goods to the value of the other materials (§47, §48, §50 BGB-German Civil Code). The purchaser is committed to keep the goods in safe custody.

4. Warranty liability

4.1 Apparent defects, wrong supplies and wrong quantities must be notified immediately in writing, within 14 days of receipt of the goods. Latent defects have to be notified in writing, immediately after being ascertained. Subsequent complaints cannot be considered.

4.2 Where complaints are justified, any deficit in the goods delivered shall be made up at a later date and in all other cases we undertake to exchange the goods as appropriate, admit their return or grant a price reduction to the purchaser. If, in the case of an exchange, the substitute supply is also defective, the purchaser has the right to annulment or price reduction.

4.3 In all other cases we are liable only for wrongful intent or gross negligence, which has to be proven by the purchaser. This liability is limited to the purchase price of goods supplied.

V. Special Conditions for Services

1. Execution of the order

1.1 The orders accepted by us are carried out according to the acknowledged rules of science and technology, where such exist, and in consideration of the existing statutory and official regulations.

1.2 Where assistance is required from the purchaser or from a third party, this must be furnished in accordance with the effective statutory or official regulations.

2. Liability

2.1 We are liable for faulty services or damage during the execution of the services where this is proven to have been caused with intent or by gross negligence. Liability is limited to compensation of the direct damage. For damage caused by actions or default in connection with the performance of the contract, liability is limited to the maximum amount covered by the Company's liability insurance, wherein the maximum amount is the contract value.

2.2 The customer agrees to exempt us from any compensation claims by third parties in respect of the unrestricted or restricted further utilisation of our services.

VI. Delay, Force Majeure

1. Should we fail to meet the agreed deadline, the purchaser or customer shall set a reasonable final deadline for us in writing. After expiry of this deadline, the purchaser or customer has the right to withdraw from the contract. Other claims can only be made in the case of wrongful intent or gross negligence. Damages caused by delays are restricted to the purchase price or contract value.

2. Notwithstanding sub-paragraph 1, war, strike, lockout, shortage of raw materials and energy, production or traffic stoppages, acts decreed by public authorities or other cases of force majeure release us from the obligation to supply or render services. This also applies if the supply or service is overdue at the time the stoppage occurs. In such a case, we have the right to rescind the contract totally or partially without the purchaser having the right to compensation.

VII. Payments

1. Invoices for supplies are payable within 30 days of the date of invoice. Invoices for services are payable immediately after the receipt of invoice, without deduction in each case. The presentation of bills of exchange requires our prior consent.

The stamp duty and expenses on bills of exchange as well as bill discounts according to normal banking practice are charged to the purchaser's account from the date our claim is due.

2. The payments are only deemed to be effected when the total amount has finally been received.

3. Any right of the purchaser to withhold payment is excluded. In the same way, the purchaser's right to offset payment is excluded, unless the amount is offset with uncontested or legally valid claims.

4. If the period allowed for payment is exceeded, we reserve the right to charge interest amounting to 2% above the current bank rate of the German Federal Bank.

5. We reserve the right to use payments to settle the longest-standing invoices including the accrued default interest.

VIII. Place of Performance, Place of Jurisdiction

1. Place of performance for supplies is the despatch point; place of performance for services in Essen; place of performance for payments is Essen.

2. Place of jurisdiction for the parties to the contract is Essen. However, we also reserve the right to assert our claims in a court of competent jurisdiction for the purchaser or customer.

Auswahl aus dem
Brandschutz-Schrifttum ab 1962

- 1 Both: Das frühzeitige Erkennen von Grubenbränden mit Meßgeräten. Glückauf Nr. 24 (1962) S. 1406/1413
- 2 Müller, R.: Verfahren zur Verhütung von Selbstentzündungsbränden in abgeworfenen Grubenbauen und Bruchbaustreben der Saarbergwerke AG. Glückauf 103 (1967) Nr. 22, S. 1125/31
- 3 Both: Erfahrungen mit Kohlenmonoxid-Schreibern beim frühen Erkennen von Grubenbränden. Glückauf Nr. 3 (1968) S. 135/138
- 4 Both: Verhütung von Selbstentzündungsbränden in Abbaubetrieben durch Unterbinden von Schleichwetterströmen. Glückauf Nr. 7 (1972) S. 237/242
- 5 Both: Löschen offener Grubenbrände. Glückauf Nr. 25 (1972) S. 1195/1200
- 6 Both/Stark: Bekämpfung eines verdeckten Grubenbrandes mit Druckausgleich auf der Zeche Ewald-Fortsetzung. Glückauf Nr. 13 (1974) S. 514/517
- 7 Schubert/Both: Die Maßnahmen zur Stabilisierung der Bewetterung bei Auftreten offener Grubenbrände. Glückauf Nr. 25 (1974) S. 22/25
- 8 Hauptstelle für das Grubenrettungswesen, Essen: MERKBLATT für den Einsatz von CO-Meßeinrichtungen (1975)
- 9 Kugler/Schewe: Bekämpfung eines Grubenbrandes auf der Zeche Osterfeld durch Einleiten von Stickstoff. Glückauf Nr. 10 (1975) S. 467/472
- 10 Both/Schönfeld: Bekämpfung eines verdeckten Grubenbrandes durch Einleiten von Stickstoff. Glückauf Nr. 20 (1975) S. 979/982
- 11 Hauptstelle für das Grubenrettungswesen, Essen: MERKBLATT für die Inertisierung mit Stickstoff bei der Grubenbrandbekämpfung (1976)

Auswahl Brandsch 4-Schrifttum

Bl. 2

- 12 Müller: Bekämpfung eines verdeckten Grubenbrandes durch Inertisierung mit Stickstoff. Glückauf Nr. 14 (1976) S. 810/816
- 13 Both/Weinheimer: Ein bemerkenswerter Selbstentzündungsbrand auf dem Verbundbergwerk Haus Aden. Glückauf Nr. 3 (1976) S. 117/122
- 14 Genthe/Schönfeld: Die Bekämpfung eines offenen Grubenbrandes mit Objektinertisierung durch Stickstoff. Glückauf Nr. 8 (1977) S. 407/411
- 15 Ruhrkohle AG, Essen: HANDBUCH ARBEITSSICHERHEIT "Verhütung von Selbstentzündungsbränden", 12/1978, Nr. 801 302
- 16 Hauptstelle für das Grubenrettungswesen, Essen: MERKBLATT Einsatz von Prozeßrechtern zur Früherkennung von Grubenbränden (1979)
- 17 Both/Müller: Grubenbrandbekämpfung mit Stickstoff im deutschen Steinkohlenbergbau. Glückauf Nr. 19 (1979) S. 944/949
- 18 Brändle u.a.: Erfolgreiche Bekämpfung einer CO-Entwicklung durch das Druckausgleichsverfahren. Glückauf Nr. 2 (1980) S. 57/63
- 19 Müller: Die Bedeutung der Brandkennziffer für die Grubengasabsaugung. Glückauf 116, Nr. 5 (1980) S. 205/208
- 20 Genthe: Inertisierungstechnik bei der Grubenbrandbekämpfung. bergbau Nr. 7 (1980) S. 400/408
- 21 Hein/Kock: Anwendungstaktik und Aufgaben der Grubenwehr bei der Grubenbrandbekämpfung mit Stickstoff. Glückauf 116 Nr. 15 (1980) S. 770/774

Auswahl Brandschutz-Schrifttum

B1. 3

- 22 Both: Brandschutz im Steinkohlenbergbau. bergbau Nr. 8, 1980, S. 472/473
- 23 Steinkohlenbergbauverein: Beurteilung der Analysenergebnisse von Grubenbrandgasproben, (1981). Verlag Glückauf GmbH, Essen
- 24 Both: Fighting Mine Fires with Nitrogen in the German Coal Industry. The Mining Engineer, Vol. 140, No. 236, (Mai 1981)
- 25 Harris: The Use of Nitrogen to Control Spontaneous Combustion Heatings. The Mining Engineer, Vol. 140, No. 237, (Juni 1981)
- 26 Both, Linhart, Pollak, Schubert: Abschätzung des Brandauftriebs in geneigten Grubenbauen auf der Grundlage der vorhandenen Brandbelastung. Glückauf Nr. 5 (1982) S. 253/257
- 27 Kock, F.-J.: Selbstrettungstechnik im Steinkohlenbergbau. Berg- und Hüttenmännische Monatshefte, Sonderdruck aus Jg. 127, Heft 2, 1982
- 28 Steinkohlenbergbauverein, Essen: Hinweise zur Selbstrettungs-, Rettungs- und Brandschutztechnik bei der Auffahrung von sonderbewetterten Strecken mit Vollschnittmaschinen. (Rundschreiben Nr. MZ 22 vom 2.12.1982)
- 29 Zillessen, Ch.: Erzeugung von Inertgas für die Grubenbrandbekämpfung mit einer neuen Luftzerlegungsanlage. Glückauf Nr. 16 (1983) S. 776/81
- 30 Steinkohlenbergbauverein, Essen: Hinweise zum Verhüten und Bekämpfen von Gasbränden in Streckenvortrieben mit Teilschnittmaschinen. (Rundschreiben Nr. MZ 18 vom 9.12.1983)
- 31 Langer, Georg: Besondere sicherheitliche Gesichtspunkte beim Auffahren überlanger sonderbewetterter Strecken. Glückauf Nr. 2 (1984) S. 93/96

Auswahl Brandschutz-Schrifttum

Bl. 4

- 32 Plate, Manfred: Brandschutztechnische Absicherung von Vortriebsmaschinen und Fördermitteln. Glückauf Nr. 18 (1985), S. 1369/1374
- 33 Hein, Norbert: Maßnahmen zum Verhüten, Erkennen und Bekämpfen von Grubenbränden. Glückauf Nr. 7 (1984), S. 407/408
- 34 Langer, G.: Organisation und Einrichtungen zur Selbstrettungstechnik im Steinkohlenbergbau unter Tage. Glückauf Nr. 7 (1984), S. 411
- 35 Linberg, Burkhard: Brandschutztechnische Sicherungsmaßnahmen bei Schweiß- und Brennarbeiten. Kompaß, Heft 4 (1984), S. 173/175
- 36 Kock, F.-J.: Grubenwehren und Brandbekämpfung im deutschen Bergbau. Glückauf 121 (1985), Nr. 1, S. 19/28
- 37 Kock, F.J., und B. Linberg: Strategie der Brandbekämpfung mit Stickstoff. Glückauf 121 (1985), Nr. 18, S. 1377/1385
- 38 Helmut Berndt und Meinhard Funkemeyer: Erfolgreiche Bekämpfung eines verdeckten Grubenbrandes auf dem Bergwerk Niederberg. Glückauf 122 (1986) Nr. 7, S. 490/498
- 39 Walther Both, Bernhard Rauß und Dieter-Peter Sittek: Bekämpfen eines verdeckten Brandes auf dem Bergwerk Heinrich Robert. Glückauf 122 (1986) Nr. 14, S. 942/948
- 40 Funkemeyer, M., und G. Habenicht: Abbau von Flöz Sonnenschein bei großflächiger Oxidation eines Begleitflözes im Alten Mann. Glückauf 123 (1987), Nr. 22, S. 1411/1417
- 41 Hein, N.: Verhüten und Bekämpfen von Gasbränden an Gewinnungs- und Vortriebsmaschinen. Kurznachrichten Steinkohlenbergbauverein Nr. 122, Dez. 1987

Auswahl Brandschutz-Schrifttum

B1. 5

- 42 Velsen-Zerweck, R. von: Wege zum verbesserten Brand- und Explosionsschutz im Steinkohlenbergbau unter Tage. Glückauf 124 (1988), Nr. 3, S. 144/157
- 43 Fauth, G., und N. Hein: Brandgas-Meßanlage für die Überwachung von Grubenbränden. Bergbau Nr. 11 (1988), S. 482/488

POLAND
CENTRAL MINING INSTITUTE
VENTILATION DEPARTMENT

**List of papers and Research Work produced
by Ventilation Department Staff, 1980 - 1988.**

Dr Ruta Cybulska
Główny Instytut Górnictwa
(Central Mining Institute)
Kopalnia Doświadczalna "Barbara"
(Experimental Mine "Barbara")
43-190 Mikołów
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POLAND

February 17, 1989.

NORWEST

Norwest Resource Consultants Ltd
Project Manager
Mr David Parkes

C a l g a r y, Alberta T2G 0R3

205 - 9th Avenue SE

Dear Mr Parkes,

In reply to your letter of 25 Nov. 1988 I am pleased to inform you that the Ventilation Department of the Central Mining Institute is dealing with problems concerning mine fires under the leadership of Prof. Dr Henryk Dystroń.

The Central Mining Institute is a research institute, which embraces among others combating all mine hazards.

In the field of mine fires we have great experience and our knowledge and achievements are on a world level.

The seams of our mines are very prone to spontaneous combustion therefore this hazard has been always of great interest and concern here. Much work has been done and positive results obtained.

I completed the questionnaire only for the Ventilation Department.

Name of Facility:

Główny Instytut Górnictwa
Zakład Aerologii Górniczej

Address: 40-951 Katowice
Plac Gwarków 1

Date Facility was constructed: 1952

Name of director: Prof. Dr Henryk Dystroń

Size of Facility: number of scientists 13
 number of engineers
 and technicians 16

The facility is conducting investigations on:

- ventilation in mines
- forecast and prevention of mine fires,
- suppression of mine fires and liquidation of mine fire fields,
- prevention and suppression of fires on heaps and coal storages.

The Facility disposes of devices and equipment for:

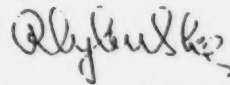
1. Ventilation methods for ventilation regions with longwalls considering spontaneous combustion of seams.
Joint research project - Maria Skłodowska-Curie Fund (USA)
Report No 1 and No 1980-1986.
2. Fire extinguishing ventilation methods for longwalls with caving.
Joint research project - Maria Skłodowska-Curie Fund (USA)
Report No 1 and No 4, 1980-1983.
3. H. Bystron
Active method of extinguishing a mine fire and the liquidation of the fire fields.
Przegląd Górniczy 12/1984, Katowice.
4. H. Bystron
Expert evidence on principles of the course of action with fire hazards in gassy longwalls with caving considering mine fires and methane explosions at the colliery "Manifest Lipcowy".
Documentation GIG - Katowice 1988.
5. Kołodziejczyk B., Muzyczuk J.:
Formation and prevention of spontaneous mine fires in coal mines.
SITG - Katowice 1985.
6. Muzyczuk J.:
The distribution of temperature in undisturbed side walls of headings.
Komunikat GIG - Katowice 1982.
7. Muzyczuk J.:
The time forecasting diagram of selfcooling of a mine fire field.
Przegląd Górniczy, Katowice 1/1985.
8. Muzyczuk J.:
General criterions for the application of Le Chatelier principle for determination explosion limits for hybrid gas mixtures.
Przegląd Górniczy - Katowice 6/1988.
9. Kołodziejczyk B., Muzyczuk J.:
Principles of fire hazard control in dead ends.
Documentation GIG - Katowice 1985.
10. Muzyczuk J.:
Courses and processes of low temperature oxydation of coal and their practical application.
Documentation GIG - Katowice 1987.

- investigations on spontaneous combustion,
- elaborating potential ventilation schemes,
- gas analyses,
- forecast of climatic hazards.

Please find enclosed a list of some papers and elaboration published by the researchers of this Facility.

Kindest regards

sincerely yours

A handwritten signature in cursive script, appearing to read 'Ruta Cybulska'.

(Ruta Cybulska)

LONDONDERRY INDUSTRIAL SAFETY CENTRE

N.S.W. AUSTRALIA

"Design of a Full Scale Fire Gallery"

DESIGN OF A FULL-SCALE FIRE GALLERY

AT THE LONDONDERRY INDUSTRIAL SAFETY CENTRE

M.R.Lloyd, A.R.Green, R.W.Bilger.

There has never been a concerted attempt in Australia to study the many problems associated with mine fires under local conditions. The provision of a full scale fire gallery goes a long way towards rectifying this problem. In Australia the states have control over the type of materials allowed underground. However, there is an urgent need to carry out investigations on materials and the effects of large fires on mine ventilation relevant to Australian mine layouts and practices. While some of this assessment can be done using small scale tests coupled to modelling techniques, there is still a need for large scale fire trials to assess the impact of the mine environment on fire ignition and propagation and to study ventilation problems, e.g. the stratification and air reversal associated with large fires.

The main criteria for design of the gallery was that it should conform to typical mine roadways and mining practices found in Australia. Consequently, the aspect ratio of width to height is maintained at 2:1. The ventilation, at least initially, will be operated in an exhaust mode and will be capable of inducing an airflow of up to 5ms^{-1} . The gallery has been designed on a modular basis in order that crosscuts can be introduced easily at positions that correspond to pillar sizes of between 40m and 70m. At a later stage complete pillars will be added for ventilation studies.

In order to assess the fire hazards of materials or to be useful for ventilation studies, the gallery has to be extensively instrumentated, with processing of

the data by computer. The data is then available in a form readily assimilated for model or comparison studies.

The design of the proposed gallery has been discussed with overseas authorities so that the possibility of correlation of results with such authorities will be enhanced.

INTRODUCTION

A fire hazard exists in many underground mining situations through the use of flammable materials. The degree of the hazard depends on a number of factors related to the fuel or material itself as well as the environment in which the material is located. Material flammability can be studied under laboratory conditions, but the behaviour in large fires can be markedly different. The fire, by preheating the material can alter its condition and composition prior to ignition. The material loading and geometry are important to fire propagation. Degradation by oil and coal dust can also affect the flammability of the material.

A large fire in a mine represents a severe hazard. The fire can disrupt the ventilation system of the mine. The fire growth will be dependent on the ventilation, gradient, size and geometry of the mine roadway in addition to the material properties discussed above.

Although there have been a number of studies applicable to mining environments only a few have been done in geometries similar to those typically found within N.S.W. Mining methods commonly adopted in N.S.W., namely Bord and Pillar and multiple entry longwalls give rise to a large number of interconnecting roadways. The effect of fires on ventilation in this type of system cannot be accurately predicted. This is a major concern as it affects the planning of

evacuation as well as the evacuation of the mine and can hamper rescue attempts and impede fire fighting.

Large fires have the ability to back up large distances against the ventilation flow at air velocities typically found in mines (1). The presence of a large number of interconnecting passages make it more likely that severe disruption to the ventilation will occur in the vicinity of a fire. The rate of fire growth is important in that it determines the time for evacuation of an area and the time in which a fire should be detected. Consequently, fire detection is an important area of research.

It has therefore been decided to build a full scale gallery to simulate a typical mine environment to study the many unresolved problems associated with mine fires. At present there are no large scale facilities to do this in Australia. The need for a full scale mine roadway at the Londonderry Centre to perform investigative work other than that associated with mine fires has been evident for some time. The fire gallery will fill this need. Additionally its use for mine rescue training has been proposed and the extent to which this is possible is being investigated.

Is it necessary to build a full scale gallery? Experience Overseas (2) with the problems of scaling results from a smaller scale to the full size condition suggests that it is. Comparison of tests on different galleries suggest that fires scale according to cross-sectional area. Too small a facility does not accurately reproduce what is occurring on the larger scale. Furthermore any recommendation for changing practices arising from research on a smaller facility will not be readily accepted unless there is some data base to justify conclusions arrived at on scaled studies. This inevitably means some comparison between the small and larger scales. Consequently there will always be critics who demand fullscale verification.

The remainder of this paper deals mainly with the thermal design criteria although it also briefly describes the new gallery.

DESIGN CRITERIA

Size and Geometry

In order to assess mine fire hazards, the fire gallery should ideally reproduce the typical mine roadways and typify mining practices in N.S.W. In practice, however, constraints on the budget necessitate some compromise on the size and construction of the structure.

Bord and Pillar or multiple entry roadways in N.S.W. have rectangular roadways with a standard width of 5.5m. There is not much variation in width of these roadways although in practice the effective width can be considerably less due to spalling of the sides and the introduction of obstacles such as props or brattice. Typical heights vary from 2m to 3m but a reasonable average is 2.4m. Since a major cost involved in construction is the lining of the gallery and this increases with increasing surface area it was decided to design the gallery on an aspect ratio width to height of between 2:1 and 2.3:1 based on the height of 2.4m. This is significantly different from most other galleries around the world which approximate to square cross-sections.

In order to simulate the ventilation pattern in a mine, the gallery should ideally consist of some intersecting roadways forming 50m pillars to enable air to bypass the fire zone and create stagnation conditions at the fire, although the actual sizes can vary from 40m to as much as 90m. Often one complete pillar is situated in an inclined plane angled about the point of intersection. In order to maintain the cost of the gallery within original budgetary estimates the original proposal allows for only one roadway with two crosscuts as shown

in Fig. 1. The length of the primary fire zone will be 50m followed by the crosscut and a secondary fire zone of 75m leading to the fan and chimney. Fires can also be lit in the crosscuts. In consequence a wide variety of ventilation patterns can be simulated. It is intended to extend this gallery, to include a complete pillar as well as one on an inclined plane. The fan used for ventilating the gallery will be operated in an exhausting mode (at least initially), typical of Australian mines. Ventilation velocities are generally between 0 and 3m/s but the fan will be capable of inducing higher velocities.

Thermal Properties

The development of a fire in the gallery will be influenced by the thermal properties of the walls. It is important to match as near as possible the thermal properties of the gallery to those that commonly occur in the mine.

Kennedy and Taylor (3) have shown that an important property in determining gas temperatures downstream of a fire in a ventilated passage is $kp_w c_w$ where k is thermal conductivity, p_w is the density and c_w is the specific heat of the wall material. This property should be matched as near as possible to that typically found. Table 1 shows the values of $kp_w c_w$ for some common materials together with their absorptivities, a . In order for the wall to be considered as being infinitely thick, the conduction of heat through the wall should not have influenced the temperature of the outside surface during the timespan of the fire. The thickness required, x_w , is given by

$$x_w \sim 2 (at)^{\frac{1}{2}} \quad (1)$$

where t is the duration of the fire or duration of the observation.

The emissivity and reflectance of the surfaces should also be approximately matched, since radiation can be very important to fire development. There is little data currently available but a value of 0.9 for the emissivity probably

represents the mine environment.

Table 1 Thermal Properties of Some Common Materials

Material	$k\rho_w c_w \times 10^{-6}$ $W^2 s m^{-4} K^{-2}$	$a \times 10^7$ $m^2 s^{-1}$
Coal	0.45	1.2
Sandstone	2.9	11.6
Common Brick	0.88	5.2
Chrome Brick	5.9	9.2
Fire Clay Brick	2.0	5.4
Concrete	2.5	7.5

The Characteristics of Large Fires

The likely temperatures that will be found in large fires need to be estimated to enable the correct choice of wall materials to be made as well as indicate the upper limit on the type of fire that can be set in the gallery without damage to the gallery. The gas temperature near the exhaust fan has to be estimated to determine the type of fan to be used and whether there is a need for preconditioning of the exhaust gases.

There are several reports in the literature concerned with the burning of wood. Consequently it was decided to determine the temperature profiles for a worst case based on the burning of wood. The average temperatures of the gases leaving the fire T_g^0 , assuming there are no heat losses, can be given by

$$T_g^0 = T^0 + Q_w / (t_b V A \rho_c + M_w c) \quad (2)$$

where T^0 is the ambient temperature, Q_w is the total heat available from a mass of wood, M_w , burning for a time, t_b is an air stream of velocity, V and duct cross-section A . Table 2 shows the values of the gas temperature for burning

600kg of wood using the lower heating value of wood as 17.8 MJ kg^{-1} . Although it is possible to burn wood to attain average gas temperatures in excess of 1200°C , this will only occur if sufficient surface area of wood is exposed. Block (4) gives the maximum burning rates R for open-packed wood cribs burning in the open as

$$R = C A_s b^{-\frac{1}{2}} \quad (3)$$

where A_s is the exposed surface area of the wood and b is the stick thickness. C is a constant. This can be related to the mass of wood by

$$R = 8 M_w b^{-3/2} \quad (4)$$

assuming the value of C/p from Block's data and $A_s = 3.2V_s/b$ where V_s is the volume of wood in an open packed crib.

Table 2 Average gas temperatures produced by burning 600kg of wood

t_b (s)	1020	2000	5000	1000	14400
T_g^0 (C)	1199	644	275	149	110
Q (MW)	10.5	5.4	2.1	1.07	0.71

From Eqs. (4) and (2) it can be shown that the 600kg of wood would have to be burnt as 0.04m sticks of wood in order to achieve average temperatures greater than 1200°C even allowing for the enclosing of the fire.

Assuming that the fire is built on the floor of the gallery, the fire plume will rise and impact on the ceiling. Cold air will flow into the base of the fire and the impacted plume will spread out radially across the gallery roof, being turned by the side walls and eventually flowing upstream and downstream along the gallery roof.

Thomas (1) has shown that backflow in a duct against the air stream occurs if

$$\Delta p gD / \rho V^2 > 1 \quad (5)$$

where $\Delta\rho$ is the change in density, D is the duct height, and g is the ventilation velocity.

This criteria is easily satisfied in the proposed gallery at ventilation velocities below 4.4 m sec^{-1} . Hwang et al (5) show that the plume is bent some .03m at most in the direction of the ventilation current at the higher ventilation velocities found in mines. In consequence a symmetrically impacting plume is probably a good model to calculate the degree of mixing in the fire zone, although there will be some differences from wall fires.

A fire with a base area of 3 m^2 and made from 0.06m sticks will have a free burning height of 5m (6). In a duct of 2.5m flames will appear in the turned ceiling jet with temperatures on the plume centreline of 1000°C . Heskestad's formulae (6) for centreline velocities and radius gives an impact velocity of 12 m s^{-1} and radius just before impact of 0.7m. The ceiling jet will have a depth of 0.12m and a radius of 1.4m. As it hits the ceiling the flame has already entrained 40% of the available air. Heskestad also indicates that the ceiling plume mixes very rapidly. At a radius of 2m the ceiling jet temperature will have dropped to 600°C which Table 1 indicates is about the temperature of the fully burned and mixed gas flame. All the cold air must have been entrained by this stage. In practice the ceiling jet will continue to mix establishing a complicated three dimensional recirculation pattern for this intensity of fire (5MW). For fires of greater intensity the plume re-entrainment will be even more developed, with the products leaving the fire zone well mixed. The temperatures given in Table 2 will be good estimates of the temperature of gases leaving the fire zone. Fires of lesser intensity will not behave in this manner. Some temperature stratification of the flow will occur downstream of the fire. Litton et al (7) indicate that in these well ventilated cases ceiling temperatures of about twice the bulk gas temperature will be attained some 50m from the fire. This would have to occur at small heat release rates to be consistent with the mixing data of Heskestad (6).

Hwang et al (5) give some information on the spread of fire products upstream of the fire, although no information on the temperature drop is given. Since this situation is similar to that discussed by Heskestad (6), the temperature should have dropped below 200°C within 6m of the fire. Wall and ceiling temperatures in this field will be strongly affected by radiation which could be as high as 120 kWm⁻². Under these conditions the walls and ceiling would rapidly approach the adiabatic bulk gas temperatures.

Far Field Temperatures

The gas and wall temperatures downstream of the fire will be affected by the heat lost to the walls. Kennedy and Taylor (3) provide an analysis of this type of problem and give a solution for constant heat transfer coefficient, h , from gas to walls for a constant inlet gas temperature, T_g^0 . The gas temperature, T_g is given as a function of distance, x , by

$$T_g/T_g^0 = hP/c_p AV \exp(h^2 t_v / k p_w c_w) \operatorname{erfc}(h^2 t_v / k p_w c_w)^{1/2} \quad (6)$$

and the wall temperature T_w by

$$T_w/T_g = 1 - \exp(h^2 t_v / k p_w c_w) \operatorname{erfc}(h^2 t_v / k p_w c_w)^{1/2} \quad (7)$$

where t_v is the corrected time, $t - x/V$, and P is the duct perimeter.

The gas and wall temperatures as a function of the heat transfer coefficient are shown in Figs 2 and 3 for different distances from the fire. Fig 2 depicts the case of simulating coal walls with sandstone roof and floor while Fig 3 depicts the simulation of coal walls roof and floor. The corrected time in both cases is 4 hrs. and the gas temperature is 1200°C. It is expected that the heat transfer coefficient will fall from about 100 Wm⁻²k⁻¹ near the fire source to about 10 Wm⁻²k⁻¹ some 100m from the fire. The fan will be situated about 100m from the fire. In practice a fire capable of producing an average gas temperature of 1200°C at the downstream edge of the fire would only burn for 1200 secs. at most. Under these conditions all the fan temperatures are well

below 500°C as is indicated in Table 3. Less intense fires burn for a longer period of time, but the average gas temperature leaving the fire zone is less. It would appear that for most practical situations the gas temperature at the fan would be below 500°C.

Table 3: Gas Temperatures in the Gallery

HEAT TRANSFER COEFFICIENT = $10. \text{ W m}^{-2} \text{ K}^{-1}$

$k p_w c_w \times 10^6$	2.9 roof & floor, 0.45 sides			1.0 all sides			0.45 all sides		
Initial Gas Temp (°C)	1200		600	1200		600	1200		600
Time (secs) x (m)	14400	1000	14400	14400	1000	14400	14400	1000	14400
10	1130	1050	570	1140	1080	580	1180	1080	590
25	1000	850	505	1040	900	530	1090	910	550
50	820	600	415	890	670	450	970	700	490
75	670	440	340	760	500	390	870	530	440
100	550	370	280	650	360	330	780	400	390

SUMMARY

N.S.W. mines tend to have roadways of either all coal walls, ceilings and floors or coal wall and sandstone ceilings and floors. The ratio is about 60:40. The gallery will have brick and castable linings which simulate the heat soak characteristics of an all coal environment. Data available on bituminous coal ranges from 0.28 to $0.5 \times 10^6 \text{ W}^2 \text{ s m}^{-4} \text{ K}^{-2}$. This involves the use of mildly

insulating refractory materials with thicknesses of less than 0.20m. Indeed only half this thickness is required except in the roof in the fire zones. The temperatures of the walls, roof and floor are unlikely to exceed 600°C on the inside except near the fire zone where 1200°C should be a safe upper limit. The walls and roof of the gallery should be protected against direct sunlight and these and the floor should be protected against incursion of moisture. No air gap should be left on the inner skin.

Provided that the refractories with heat soak characteristics outlined above are used, the gas temperature at the inlet to the fan should not exceed 500°C. A simple water spray will be installed for emergency use to prevent over-temperature running of the fan rather than shutting down the fan which would lead to severe problems in the fire zone and high temperatures into the fan.

Precautions have to be taken to avoid undue influence on the air flow by external winds. A high resistance at the entrance, such as a slatted screen will prevent this. Small jets at the entrance also decreases the length that is required to attain a fully mixed turbulent flow.

ACKNOWLEDGEMENTS

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REFERENCES

1. Thomas P.H.; The Movement of Smoke in Horizontal Passages Against an Airflow, Fire Research Note 723, Fire Research Station, Borehamwood, 1968.
2. Furno A.L.; Private Communication.

3. Kennedy M. and Taylor G.; Brit. J. Appl. Phys., 18, 1967, 349 - 356.
4. Block J.A.; Thirteenth Symposium (International) on Combustion, 1971, 971 - 978.
5. Hwang C.C., Chaiken R.F., Singer J.M. and Chi D.N.H., Sixteenth Symposium (International) on Combustion, 1977, 1385 - 1395.
6. Heskestad G.; Pressure Profiles Generated by Fire Plumes Impacting on Horizontal Ceilings, Factory Mutual Technical Report: FMRCJI.OFOE1.20
7. Litton C.D., Hertzberg M., Furno A.L.; Eighteenth Symposium (International) on Combustion, 1981, 633 - 639.

NOTE:

Any opinions expressed in this paper are those of the authors and do not necessarily represent the views of the New South Wales Department of Industrial Relations.

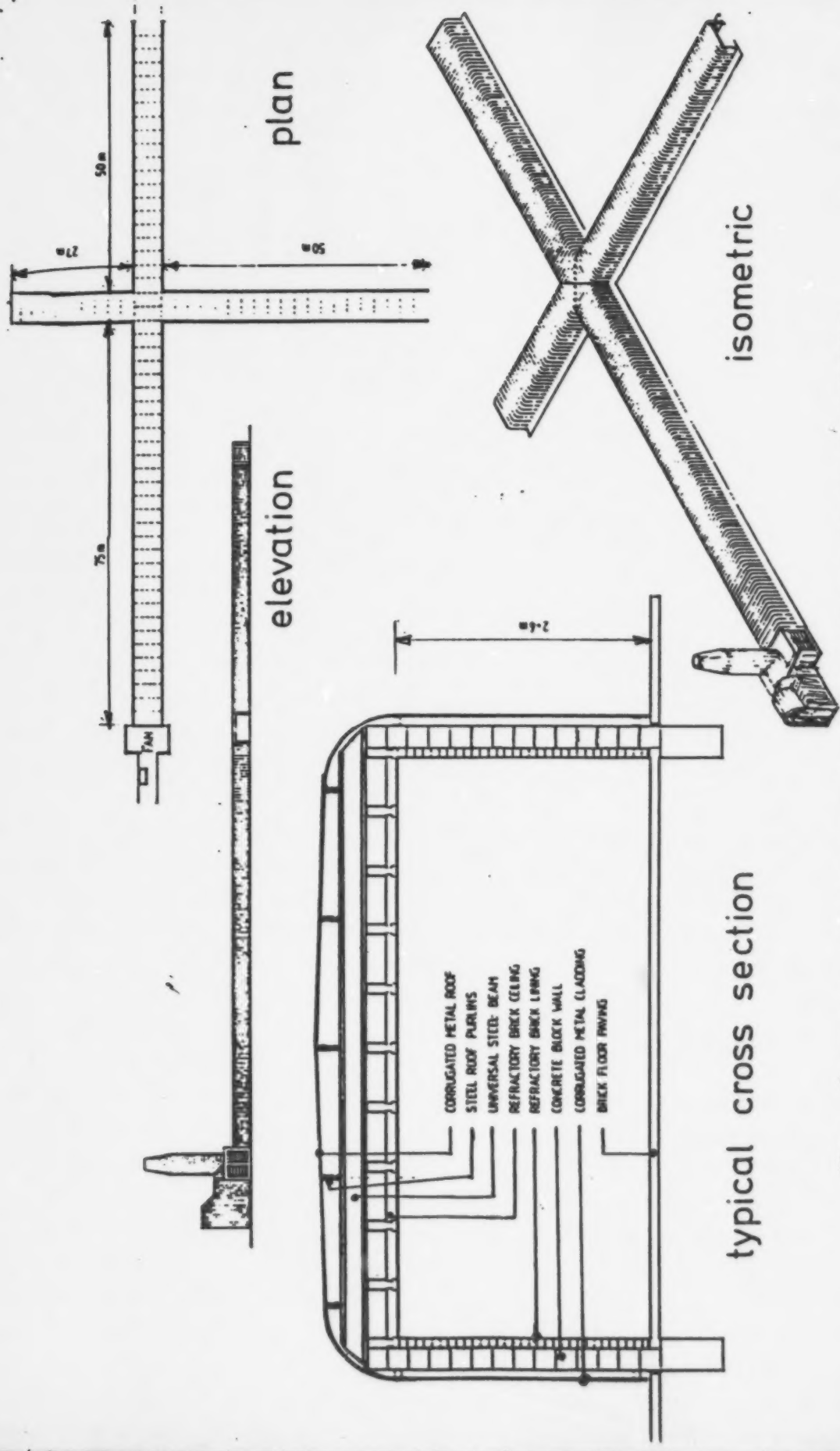


Fig. 1: FIRE GALLERY - LONDONDERRY CENTRE

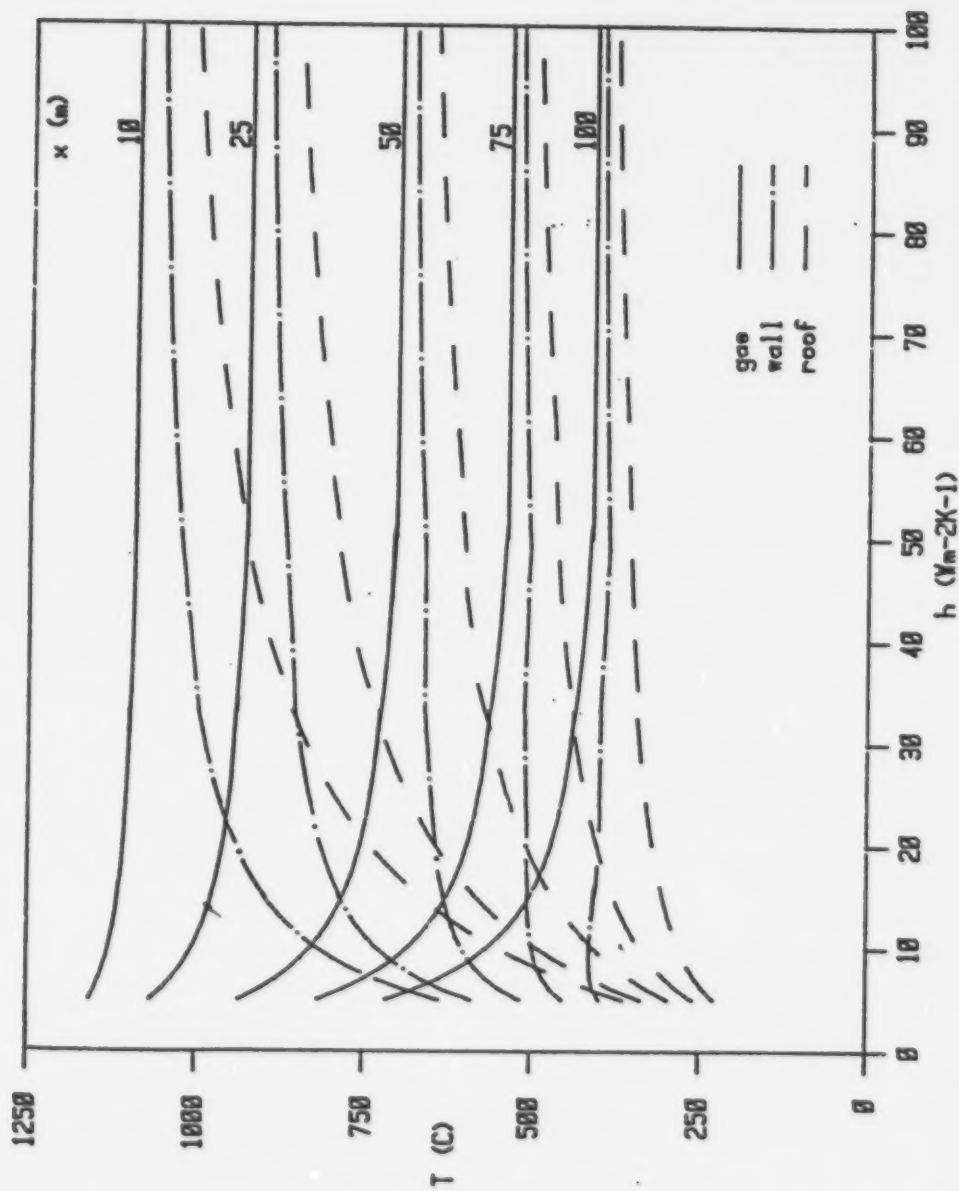


Fig.2 Predicted temperatures for a coal wall and sandstone roof simulation

$$T_g^0 = 1200^\circ\text{C}; t_v = 14400 \text{ s}$$

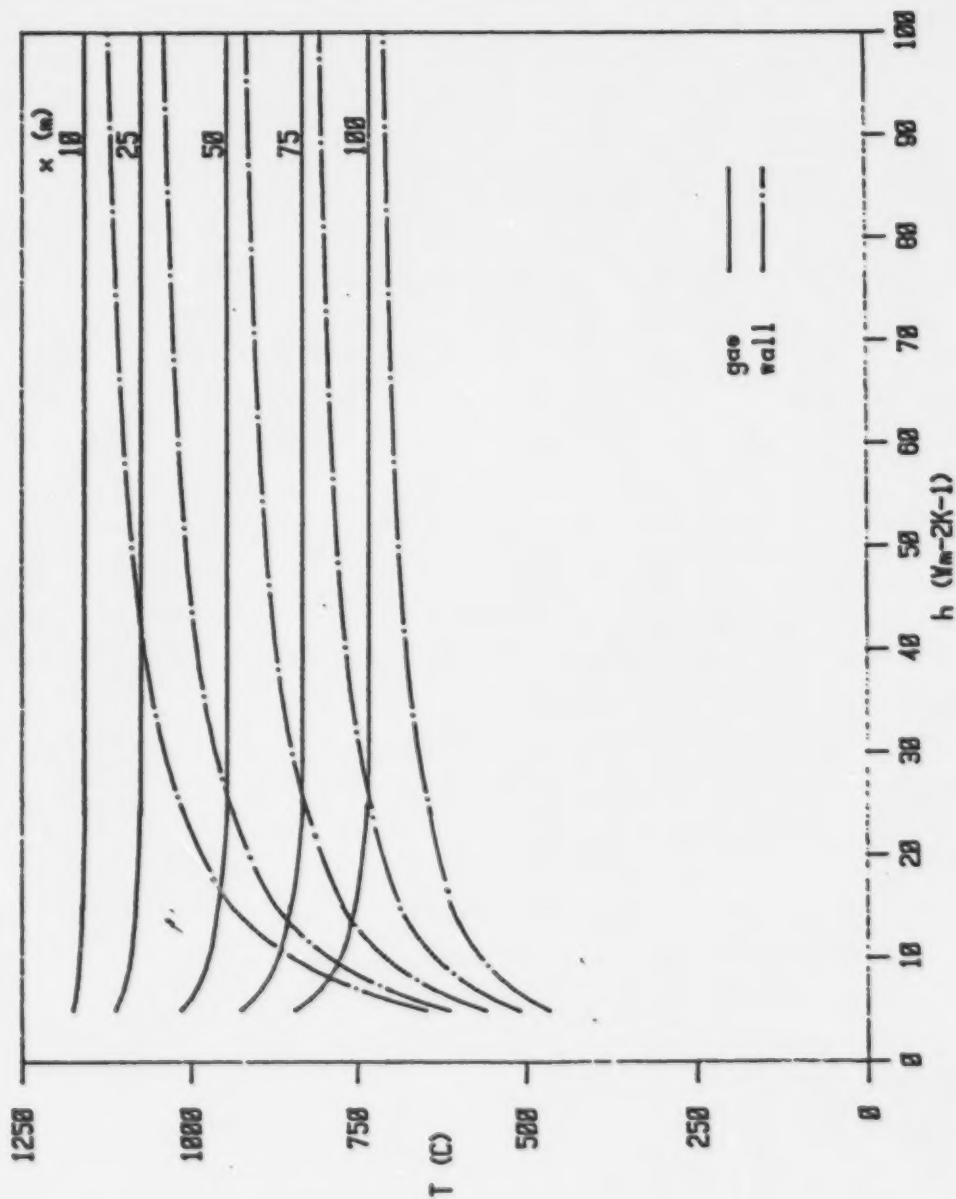


Fig.3 Predicted temperatures for a coal wall and roof simulation

$$T_g^0 = 1200^\circ \text{C}, t_v = 14400 \text{ s}$$

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Recent Presentations and Publications of the Fires and Explosions Group.

6. FIRES AND EXPLOSIONS
A. DETECTION AND FLAMMABILITY CHARACTERISTICS

CONTRACT PUBLICATIONS

BUROUGH, I. G. (ANDROS ANALYZERS, INC., H0377072, G. SCHANKENBER, TPO, PRC). DEVELOPMENT OF A CONTINUOUS METHANE MONITOR. OFR 93-82, 1981, 45pp.; NTIS: PB/82-244245.

KAWAHATA, M., LAZZARO, R. (ENVIRONMENT/ONE CORP., J0100003, J. CHILTON, TPO, PRC). POISONING OF CATALYTIC METHANE SENSORS. OFR 87-82, 1981, 156pp.; NTIS: PB/82-243973.

LILIENFELD, P. (GCA CORP., H0308010, K. CASHDOLLAR, TPO, PRC). HIGH CONCENTRATION DUST MONITOR. OFR 159-81, 1981, 76pp.; NTIS: PB/82-139320.

MARSHALL, M. D. (MSA RESEARCH CORP., J0199031, THIMONS, E., TPO, PRC). ASSESMENT OF DISPERSING TRACER GAS WITH VENTILATION AIR STREAM TO DETECT MINE FIRES. OFR 117-84, 1983, 69pp.; NTIS: PB/84-202696.

MULDOON, T. L., LEWTAS, T., GORE, T. E. (FOSTER-MILLER ASSOC., INC., H0292002, W. POMROY, TPO, TCRC). UPGRADE STENCH FIRE WARNING SYSTEM--SYSTEM DEVELOPMENT AND PROTOTYPE TESTS. OFR 136-81, 1981, 142pp.; NTIS: PB/82-122128.

OTAGAWA, T., ZAROMB, S., STETTER, J. R. (ARGONNE NATIONAL LABORATORY, H0233005, PRC). DEVELOPMENT OF A METHANE MONITOR MEETING THE BUREAU OF MINES INTRINSICALLY SAFE MINE MONITORING SYSTEM (ISMMS) REQUIREMENTS. OFR 30-87, 1984, 60pp.; NTIS: DE 85-009663.

SHIBE, J. A. (NATIONAL BUREAU OF STANDARDS, J0100053, PRC). SYSTEMS APPROACH TO MINE FIRE SAFETY. OFR 35-87, 1987, 148pp.; NTIS: PB 87-227898.

SKALA, G. F. (ENVIRONMENT/ONE CORP., H0387025, C. LAZZARA, TPO, PRC). DEVELOPMENT OF SELECTIVE SUBMICROMETER PARTICULATE FIRE DETECTORS FOR UNDERGROUND METAL MINES--IN-MINE EVALUTION. VOLUME II. OFR 58(2)-83, 1982, 36pp.; NTIS: PB/83-178954.

SKINNER, G. T., DUNN, M. G., HIEMENZ, R. J. (CALSPAN CORP., ADV. TECH. CNT., H0377029, G. SCHNAKENBG, TPO, PRC). HEAT-PULSE ANEMOMETER FOR MEASURING AIR VELOCITIES IN THE RANGE 0.4 TO 7 FEET PER SECOND. PART I: DEVELOPMENT. PART II: MICROPROCESSOR-BASED INSTRUMENT. OFR 159-83, 1982, 110pp.; NTIS: PB/83-256917.

TEWARSON, A. (FACTORY MUTUAL RES. CORP., J0395125, PRC). FIRE HAZARD EVALUATIONS OF MINE MATERIALS IN A SMALL-SCALE COMBUSTIBILITY APPARATUS. OFR 77-83, 1982, 79pp.; NTIS: PB/83-196204.

IN-HOUSE PUBLICATIONS

BURGESS, D. S., FURNO, A. L., KUCHTA, J. M., MURA, K. E.
FLAMMABILITY OF MIXED GASES. RI 8709, 1982, 20pp.

CASHDOLLAR, K. L., LIEBMAN, I., CONTI, R. S. THREE BUREAU OF MINES
OPTICAL DUST PROBES. RI 8542, 1981, 26pp.

EGAN, M. R. TRANSFORMER FLUID FIRES IN A VENTILATED TUNNEL. IC 9117,
1986, 13pp.

HERTZBERG, M. THE THEORY OF FLAMMABILITY LIMITS. CONDUCTIVE-CONVECTIVE
WALL LOSSES AND THERMAL QUENCHING. RI 8469, 1980, 25pp.

HERTZBERG, M. THE THEORY OF FLAMMABILITY LIMITS. RADIATIVE LOSSES AND
SELECTIVE DIFFUSIONAL DEMIXING. RI 8607, 1982, 38pp.

HERTZBERG, M. THE THEORY OF FLAMMABILITY LIMITS. FLOW GRADIENT EFFECTS
AND FLAME STRETCH. RI 8865, 1984, 36pp.

KUCHTA, J. M., ROWE, V. R., BURGESS, D. S. SPONTANEOUS COMBUSTION
SUSCEPTIBILITY OF U.S. COALS. RI 8474, 1980, 34pp.

LAAGE, LINNEAS, POMROY, WILLIAM, WEBER, THOMAS. COMPUTER MODELING OF
THE EFFECT OF MINE-FIRE-INDUCED VENTILATION DISTURBANCES ON STENCH FIRE
WARNING SYSTEM PERFORMANCE. IC 9154, 1987, 12pp.

LITTON, C. D. DESIGN CRITERIA FOR RAPID-RESPONSE PNEUMATIC
MONITORING SYSTEMS. IC 8912, 1983, 23pp.

LITTON, C. D. GUIDELINES FOR SITING PRODUCT-OF-COMBUSTION FIRE SENSORS
IN UNDERGROUND MINES. IC 8919, 1983, 13pp.

LITTON, C. D., HERTZBERG, M., FURNO, A. L. FIRE DETECTION SYSTEMS IN
CONVEYOR BELT HAULAGE WAYS. RI 8632, 1982, 26pp.

PANKRATZ, L. B. THERMODYNAMIC PROPERTIES OF ELEMENTS AND OXIDES. B 672,
1982, 509pp.

PERZAK, F. J., LAZZARA, C. P., KUBALA, T. A. FIRE TESTS OF RIGID
PLASTIC VENTILATION DUCTS. RI 9085, 1987, 16pp.

POMROY, W. H. SPONTANEOUS COMBUSTION FIRE DETECTION FOR DEEP METAL
MINES. IC 9144, 1987, 25pp.

POMROY, W. H., HELMBRECHT, R. E. DESIGN AND OPERATION OF FOUR PROTOTYPE
FIRE DETECTION SYSTEMS IN NONCOAL UNDERGROUND MINES. IC 9030, 1985,
25pp.

POMROY, W. H., MULDOON, T. L. IMPROVED STENCH FIRE WARNING FOR UNDERGROUND MINES. IC 9016, 1985, 33pp.

REIMERS, G. W., HJELMSTAD, K. E. ANALYSIS OF THE OXIDATION OF CHALCOPYRITE, CHALCOCITE, GALENA, PYRRHOTITE, MARCASITE, AND ARSENOPYRITE. RI 9118, 1987, 16pp.

SAPKO, M. J., MURA, K. E., FURNO, A. L., KUCHTA, J. M. FIRE RESISTANCE TEST METHOD FOR CONVEYOR BELTS. RI 8521, 1981, 27pp.

SMITH, A. C., LAZZARA, C. P. SPONTANEOUS COMBUSTION STUDIES OF U.S. COALS. RI 9079, 1987, 28pp.

THIMONS, E. D., MARSHALL, M. D. IN-MINE REMOTE-ACTUATED STENCH FIRE-WARNING SYSTEM. RI 8872, 1984, 6pp.

JOURNAL ARTICLES & OUTSIDE PUBLICATIONS

CASHDOLLAR, K. L., HERTZBERG, M. INFRARED TEMPERATURES OF COAL DUST EXPLOSIONS. OP 44-83, 1983, 13pp.; COMBUS. AND FLAME, V. 51, 1983, PP. 23-35.

CASHDOLLAR, K. L., SINGER, J. M., LEE, C. K., LITTON, C. D. SMOKE CHARACTERISTICS OF COAL-LINED TUNNEL FIRES. OP 40-81, 1981, 5pp.; FIRE AND MATER., V. 5, NO. 2, 1981, PP. 47-51.

CONTI, R. S., HERTZBERG, M. THERMAL AUTOIGNITION TEMPERATURES FROM THE 1.2-L FURNACE AND THEIR USE IN EVALUATING THE EXPLOSION POTENTIAL OF DUSTS. 1987, 15pp.; CH. IN INDUSTRIAL DUST EXPLOSIONS. STP 958, ASTM, 1987, PP. 45-59.

CONTI, RONALD S., ZLOCHOWER, ISAAC A. THERMAL IGNITION OF POLYMETHYLMETHACRYLATE (PMMA) PARTICLES. OP 123-87, 1987, 4pp.; PROC. 20TH FALL COMBINED TECH. MTG. OF COMB. INST. & NAT'L BUR. OF STANDARDS, PP. 37-1 TO 37-4.

HERTZBERG, M., CASHDOLLAR, K. L., NH, D. L., CONTI, R. S. DOMAINS OF FLAMMABILITY AND THERMAL IGNITABILITY FOR PULVERIZED COALS AND OTHER DUSTS: PARTICLE SIZE DEPENDENCES AND MICROSCOPIC RESIDUE ANALYSES. OP 46-83, 1982, 12pp.; PAPER IN 19TH SYMP. INT'L. ON COMBUSTION, HAIFA, ISRAEL, AUG. 8-13, 1982, PP. 1169-1180.

HERTZBERG, M., CASHDOLLAR, K. L., LAZZARA, C. P. THE LIMITS OF FLAMMABILITY OF PULVERIZED COALS AND OTHER DUSTS. OP 34-81, 1981, 13pp.; CHAP. IN "18TH SYMP. ON COMBUSTION." THE COMBUSTION INSTITUTE, PGH., PA, 1981, PP. 717-729.

KUCHTA, J. M., SAPKO, M. J., PERZAK, F. J., MURA, K. E. IMPROVED FIRE RESISTANCE TEST METHOD FOR BELT MATERIALS. OP 54-81, 1981, 11pp.; FIRE TECHNOL., V. 17, NO. 2, MAY 1981, PP. 120-130.

LAZZARA, C. P. SPONTANEOUS COMBUSTION POTENTIAL OF COAL. 1987, 0pp.; SYMP. OF SPONTANEOUS COMBUSTION. (UNIVERSITY OF CALGARY, CANADA, 11/13/87)..

MARSHALL, M. D., THIMONS, E. D., KNEEBONE, D. W., GROSS, S. CANISTER CONCEPT PROVIDES EARLY FIRE WARNING IN MINES. OP 23-82, 1982, 6pp.; MIN. CONG. J., V. 68, NO. 4, APRIL 1982, PP. 64-69.

PERZAK, F. J., SPENCER, E. R., SAPKO, M. J. TESTING OF FIRE-RESISTANT CONVEYOR BELTING. OP 88-82, 1982, 6pp.; CAN. MIN. MET. BULL., V. 75, NO. 884, AUGUST 1982, PP. 110-115.

PERZAK, F., LAZZARA, C. P., KUBALA, T. A. FIRE TESTS OF RIGID PLASTIC VENTILATION DUCTS. OP 125-87, 1987, 4pp.; PROC. COMBUSTION INST & NAT'L BUR OF STANDARDS, NOV. 2-5, 1987, PP. 101-1--101-4.

SAPKO, M. J., WATSON, R. W. A NOVEL ROCK DUST METER. 1985, 6pp.; CH. IN SAFETY IN MINE RESEARCH, 1985, PP. 421-426.

6. FIRES AND EXPLOSIONS
B. IGNITION

IN-HOUSE PUBLICATIONS

CHENG, L., FURNO, A. L., COURTNEY, W. G. REDUCTION IN FRICTIONAL IGNITION DUE TO CONICAL COAL CUTTING BITS. RI 9134, 1987, 10pp.

CHENG, L., LIEBMAN, I., FURNO, A. L., WATSON, R. W. NOVEL COAL-CUTTING BITS AND THEIR WEAR RESISTANCES. RI 8791, 1983, 15pp.

CONTI, R. S., CASHDOLLAR, K. L., HERTZBERG, M., LIEBMAN, I. THERMAL AND ELECTRICAL IGNITABILITY OF DUST CLOUDS. RI 8798, 1983, 40pp.

HANSON, B. D. CUTTING PARAMETERS AFFECTING THE IGNITION POTENTIAL OF CONICAL BITS. RI 8820, 1983, 14pp.

HERTZBERG, M., CONTI, R. S., CASHDOLLAR, K. L. ELECTRICAL IGNITION ENERGIES AND THERMAL AUTOIGNITION TEMPERATURES FOR EVALUATING EXPLOSION HAZARDS OF DUSTS. RI 8988, 1985, 41pp.

KUBALA, T. A., PERZAK, F. J., LITCHFIELD, E. L. ELECTRIC IGNITION OF LYCOPODIUM POWDER IN A MODIFIED HARTMANN APPARATUS. RI 8600, 1981, 9pp.

LARSON, D. A., DELLORFANO, V. W., WINGQUIST, C. F., ROEPKE, W. W. PRELIMINARY EVALUATION OF BIT IMPACT IGNITIONS OF METHANE USING A DRUM-TYPE CUTTING HEAD. RI 8755, 1983, 23pp.

LITCHFIELD, E., KUBALA, T., SCHELLINGER, T., ET AL. PRACTICAL IGNITION PROBLEMS RELATED TO INTRINSIC SAFETY IN MINE EQUIPMENT. FOUR SHORT-TERM STUDIES. RI 8464, 1980, 18pp.

ROEPKE, W. W., HANSON, B. D. BIT IGNITION POTENTIAL WITH WORN CARBIDE TIPS. TPR 121, 1983, 7pp.

ROEPKE, W. W., HANSON, B. D. TESTING MODIFIED COAL-CUTTING BIT DESIGNS FOR REDUCED ENERGY, DUST, AND INCENDIVITY. RI 8801, 1983, 31pp.

ROEPKE, W. W., HANSON, B. D., LONGFELLOW, C. E. DRAG BIT CUTTING CHARACTERISTICS USING SINTERED DIAMOND INSERTS. RI 8802, 1983, 30pp.

JOURNAL ARTICLES & OUTSIDE PUBLICATIONS

CECALA, A. B., O'GREEN, J., WATSON, R., JANKOWSKI, R. A. REDUCING LONGWALL FACE IGNITIONS. OP 29-85, 1985, 3pp.; WORLD MIN. EQUIP., V. 9, NO. 1, JAN. 1985, PP. 44-46.

CONTI, RONALD S., ZLOCHOWER, ISAAC A. THERMAL IGNITION OF POLYMETHYLMETHACRYLATE (PMMA) PARTICLES. OP 123-87, 1987, 4pp.; PROC. 20TH FALL COMBINED TECH. MTG. OF COMB. INST. & NAT'L BUR. OF STANDARDS, PP. 37-1 TO 37-4.

COURTNEY, W. G. PREVENTING FRICTIONAL IGNITIONS. OP 2-81, 1981, 11pp.; COAL MIN. & PROC. J., V. 8, NO. 1, JANUARY 1981, PP. 48-58.

EDWARDS, J. C. MATHEMATICAL MODELING OF SPONTANEOUS COMBUSTION OF COAL. OP 18-83, 1983, 16pp.; PRES. AT 112TH TMS-AIME ANN. MEETING, ATLANTA, GA, MARCH 6-10, 1983, TMS PAPER AB3-21.

6. FIRES AND EXPLOSIONS
C. PROPAGATION AND MONITORING

CONTRACT PUBLICATIONS

DRISCOLL, J. F., CHEN, T. H. (UNIV. OF MICHIGAN, JO199094, PRC).
LASER VELOCIMETER STUDY OF METHANE ROOF LAYERS. OFR 27-85, 1983, 77pp.;
NTIS: PB/85-185809.

GREUER, R. E. (MICHIGAN TECH. UNIVERSITY, JO285002, J. EDWARDS, TPO, PRC).
A STUDY OF PRECALCULATION OF EFFECT OF FIRES ON VENTILATION SYSTEM OF
MINES. OFR 19-84, 1983, 293pp.; NTIS: PB/84-159979.

IN-HOUSE PUBLICATIONS

CHENG, L., FURNO, A. L., COURTNEY, W. G. REDUCTION IN FRICTIONAL
IGNITION DUE TO CONICAL COAL-CUTTING BITS. RI 9134, 1987, 10pp.

EDWARDS, J. C., GREUER, R. E. REAL-TIME CALCULATION OF PRODUCT-OF-
COMBUSTION SPREAD IN A MULTILEVEL MINE. IC 8901, 1982, 117pp.

KUCHTA, J. M., FURNO, A. L., DALVERNY, L. E., ET AL. DIAGNOSTICS OF
SEALED COAL MINE FIRES. RI 8625, 1982, 30pp.

LEE, C. K., CHAIKEN, R. F., SINGER, J. M., HARRIS, M. E. BEHAVIOR OF
WOOD FIRES IN MODEL TUNNELS UNDER FORCED VENTILATION FLOW. TESTS WITH
UNTREATED WOOD. RI 8450, 1980, 58pp.

LITTON, C. D., HERTZBERG, M., FURNO, A. L., KUCHTA, J. M. MONITORING
SUBMICROMETER PARTICLES IN SEALED FIRE AREAS. RI 8586, 1981, 20pp.

WELSH, J. H. COMPUTERIZED, REMOTE MONITORING SYSTEMS FOR UNDERGROUND
COAL MINES. FIRES AND EXPLOSIVE ATMOSPHERES. IC 8875, 1982, 9pp.

JOURNAL ARTICLES & OUTSIDE PUBLICATIONS

CASHDOLLAR, K. L., HERTZBERG, M. INFRARED PYROMETERS FOR MEASURING DUST
EXPLOSION TEMPERATURES. OP 16-81, 1980, 7pp.; MODERN UTILIZATION OF
INFRARED TECHNOL. VI, SPIE, V. 253, 1980, PP. 254-260.

CASHDOLLAR, K. L., HERTZBERG, M. INFRARED PYROMETER FOR MEASURING DUST
EXPLOSION TEMPERATURES. 1982, 5pp.; OPTIC ENG., V. 21, NO. 1, JANUARY/
FEBRUARY 1982, PP. 82-86.

CASHDOLLAR, K. L., HERTZBERG, M. INFRARED TEMPERATURE MEASUREMENTS OF GAS AND DUST EXPLOSIONS. OP 74-82, 1982, 11pp.; 6TH SYMPOSIUM ON TEMPERATURE, WASHINGTON, DC, MARCH 14-18, 1982.

CONTI, R. S., CASHDOLLAR, K. L., LIEBMAN, I. IMPROVED OPTICAL PROBE FOR MONITORING DUST EXPLOSIONS. OP 12-82, 1982, 3pp.; REV. SCI. INSTR., V. 53, NO. 3, 1982, PP. 311-313.

CONTI, R. S., HERTZBERG, M., DUDA, F. T., CASHDOLLAR, K. L. RAPID-SAMPLING SYSTEM FOR DUSTS AND GASES. OP 8-83, 1983, 5pp.; REV. SCI. INSTR., V. 54, NO. 1, JANUARY 1983, PP. 104-108.

EDWARDS, J. C., JING-SHU, L. COMPUTER SIMULATION OF VENTILATION IN MULTILEVEL MINES. OP 23-85, 1984, 5pp.; THIRD MINE VENTILATION CONGRESS. HARROGATE, 1984. INST. OF MIN. AND METALLURGY, 1984, PP. 47-51.

KANSA, E. J. AN ALGORITHM FOR MULTIDIMENSIONAL COMBUSTING FLOW PROBLEMS. OP 50-81, 1981, 43pp.; J. COMPUT. PHYS., V. 42, NO. 1, JULY 1981, PP. 152-194.

KANSA, E. J., PERLEE, H. E. A TRANSIENT DUST-FLAME MODEL: APPLICATION TO COAL-DUST FLAMES. OP 31-80, 1980, 20pp.; COMBUST. FLAME, V. 38, 1980, PP. 17-36.

LAZZARA, C. P., PERZAK, F. J. EFFECTS OF VENTILATION ON CONVEYOR BELT FIRES. 1987, 0pp.; CH. IN PROC. ON SAFETY IN COAL MINES, PRETORIA, SO. AFRICA, 1987.

LEE, C. K., HWANG, C. C., SINGER, J. M., CHAIKEN, R. F. INFLUENCE OF PASSAGEWAY FIRES ON VENTILATION FLOWS. OP 111-84, 1980, 7pp.; MINE VENTILATION CONGRESS, RENO, NV, NOV. 4-8, 1979. SOC. MIN. ENG. AIME, NY, 1980, PP. 448-454.

SAPKO, M., PINKERTON, J., BUBASH, J. MONITORING THE ACCUMULATION OF HAZARDOUS DUSTS. 1987, 21pp.; PROC. SHENYANG INT'L SYMP. ON DUST EXPLOSIONS, 1987, PP. 349-369.

UNGER, R. L. A COMPUTER-BASED MODEL OF MACHINE OPERATOR COMPARTMENTS. 1985, 9pp.; PROC. IEEE INTERN'TL CONF. ON SYSTEMS, MAN AND CYBERNETICS, TUCSON, AZ 1985, PP. 147-155.

6. FIRES AND EXPLOSIONS
D. CHEMICAL AND PHYSICAL SUPPRESSIONS

CONTRACT PUBLICATIONS

AGBEDE, R. O., WHITEHEAD, K. L., MUNDELL, R. L., SALTSMAN, R. D. (BITUMINOUS COAL RESEARCH INC, J0395040, W. COURTNEY, TPO, PRC). FRICTIONAL IGNITION SUPPRESSION BY THE USE OF CUTTER-DRUM MOUNTED SPRAYS. OFR 66-83, 1982, 135pp.; NTIS: PB/83-191593.

BAIN, R. J. (UNIV. OF AKRON, G5195033, WO). CHARACTERIZATION OF OHIO LIMESTONE TO DETERMINE POTENTIAL USE IN CONTROL OF COAL EMISSIONS. OFR 38-83, 1982, 43pp.

DAVIS, M., HOLLEY, W., DIEHL, W. R. (SPRINGBORN LABORATORIES, INC, J0166068, C. LAZZARA, TPO, PRC). FURTHER STUDIES ON OPTIMUM COMBINED FIRE RETARDANT/PRESERVATIVE TREATMENTS AND STENCH WARNING SYSTEMS FOR WOOD MINE TIMBER. OFR 27-83, 1982, 82pp.; NTIS: PB/83-171975.

ESSENHIGH, R. H. (OHIO STATE UNIVERSITY, J0199018, M. SAPKO, TPO, PRC). COAL DUST COMBUSTION IN A STIRRED REACTOR: EVALUATION OF COMBUSTION AND EXTINCTION MECHANICS IN COAL DUST EXPLOSION FLAMES. OFR 67-83, 1981, 78pp.; NTIS: PB/83-191585.

GREENE, F. T., O'DONNELL, J. E. (MIDWEST RESEARCH INSTITUTE, J0166076, D. BURGESS, TPO, PRC). THE QUENCHING BEHAVIOR OF COAL DUST-AIR MIXTURES. OFR 4-83, 1981, 88pp.; NTIS: PB/83-164665.

GREUER, R. E. (MICHIGAN TECHNOLOGICAL UNIV., J0285002, J. EDWARDS, TPO, PRC). REAL-TIME PRECALCULATION OF THE DISTRIBUTION OF COMBUSTION PRODUCTS AND OTHER CONTAMINANTS IN THE VENTILATION SYSTEM OF MINES. OFR 22-82, 1981, 263pp.; NTIS: PB/82-183104.

GROSS, S. S. (MSA RESEARCH CORP., H0308064, A. FURNO, TPO, PRC). INCORPORATION OF FIRE EXTINGUISHING AGENTS IN HIGH EXPANSION FOAM. OFR 109-83, 1982, 34pp.; NTIS: PB/83-218859.

HOLLEY, W. H. (SPRINGBORN LABORATORIES, INC, J0166068, C. LAZZARA, TPO, PRC). CONTINUED RESEARCH ON COMBINED FIRE/ROT RETARDANT TREATMENT FOR WOOD MINE TIMBER. OFR 115-81, 1980, 0pp.; NTIS: PB/81-244493.

LEASE, W. D. (LEASE "AFEX", INC., H0262049, W. POMROY, TPO, TCRC). DEVELOPMENT OF AN AUTOMATIC FIRE PROTECTION SYSTEM FOR SURFACE VEHICLES. FINAL REPORT--VOLUME I. OFR 73-82, 1981, 74pp.; NTIS: PB/82-215765.

MCDONALD, L., KENNEDY, D., REID, G. (ANSUL, H0262023, G. A. JOHNSON, TPO, TCRC). IMPROVED FIRE PROTECTION SYSTEM FOR UNDERGROUND FUELING AREAS. VOLUME II. OFR 160-82, 1981, 111pp.; NTIS: PB/83-114744.

NEWMAN, J. S., KHAN, M. M. (FACTORY MUTUAL RESEARCH, CORP, HO113017, PRC) STANDARD TEST CRITERIA FOR EVALUATION OF UNDERGROUND FIRE DETECTION SYSTEMS--FINAL REPORT (INCLUDING PHASE IV). OFR 54-85, 1984, 217pp.; NTIS: PB/85-204170.

PACZKOWSKI, M., TRACEY, G. A., WOJTYCZKA, A. (CSE CORP., J0318080, R. WATSON, TPO, PRC). CMI INERT GAS MINE FIREFIGHTING SYSTEM. OFR 212-83, 1982, 58pp.; NTIS: PB/84-142678.

RUGGIERI, S. K., KIECHMANN, J. T. (FOSTER-MILLER ASSOC., INC., HO155053 R. CHAIKEN, TPO, PRC). DESIGN, FABRICATION AND DEMONSTRATION OF AN INERT GAS GENERATOR. VOLUME II - OPERATIONS AND MAINTENANCE MANUAL. OFR 72-80, 1980, 150pp.; NTIS: PB/80-207368.

RUGGIERI, S. R., GUZDAR, A. (FOSTER-MILLER ASSOCIATES, IN, HO188105, R. KING, TPO, PRC). REMOTE SEALING SYSTEM FIELD DEMONSTRATION. OFR 139-80, 1980, 65pp.; NTIS: PB/81-132490.

STEEN, C. L., SUUBERG, E. M. (CARNEGIE-MELLON UNIVERSITY, J0308032, M. HERTZBERG, TPO, PRC). KINETIC STUDIES RELEVANT TO THE SUPPRESSION OF COAL DUST EXPLOSIONS BY POWDERED INHIBITORS. OFR 162-82, 1981, 49pp.; FOR REFERENCE ONLY AT BUREAU LIBRARIES.

STEVENS, RALPH B. (ESD CORP., HO100017, TCRC). DEMONSTRATION OF A MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEM FOR COAL MINES. OFR 116-85, 1983, 294pp.; NTIS: PB/86-146933.

TARPLEY, W. B., JR., LEMON, L. H., TUNO, A. L. (ENERGY & MINERALS RES. CO., HO395081, A. FURNO, TPO, PRC). THIXOGELLED HALON/DRY POWDER FIRE SUPPRESSANTS. OFR 96-82, 1981, 46pp.; NTIS: PB/82-245937.

VANPEE, M., TYLER, R. W. (UNIVERSITY OF MASSACHUSETTS, J0395097, C. P. LAZZARA, TPO, PRC). INVESTIGATION OF EXTINGUISHING AGENTS FOR COAL DUST EXPLOSION. OFR 53-83, 1982, 83pp.; NTIS: PB/83-180885.

IN-HOUSE PUBLICATIONS

CHENG, L., PRO, R., MALCOLM, D. R., FURNO, A. L. IN-MINE INSTALLATION OF PASSIVE WATER BARRIERS. RI 8915, 1984, 9pp.

HERTZBERG, M., CASHDOLLAR, K. L., LAZZARA, C. P., SMITH, A. C. INHIBITION AND EXTINCTION OF COAL DUST AND METHANE EXPLOSIONS. RI 8708, 1982, 29pp.

JOHNSON, G. A. AUTOMATIC FIRE PROTECTION FOR MOBILE UNDERGROUND MINING EQUIPMENT. IC 8954, 1983, 12pp.

LIEBMAN, I., RICHMOND, J. K. SUPPRESSION OF COAL DUST EXPLOSION BY WATER BARRIER IN A CONVEYOR BELT ENTRY. RI 8538, 1981, 27pp.

PAPP, J. F., LAZZARA, C. P., BIORDI, J. C. STRUCTURE STUDY OF A CF₂BR₂-INHIBITED METHANE FLAME. EFFECT OF CF₂BR₂ ON COMPOSITION, NET REACTION RATES, AND RATE COEFFICIENTS. RI 8551, 1981, 32pp.

STAFF, BUREAU OF MINES. SURFACE MINE TRUCK SAFETY. IC 8828, 1980, 61pp.; BUREAU OF MINES TECH. TRANSFER SEMINARS, MINNEAPOLIS, APR. 25, AND BIRMINGHAM, AUG. 19, TUCSON.

JOURNAL ARTICLES & OUTSIDE PUBLICATIONS

CHI, D. N. H., PERLEE, H. E. FIRE-FIGHTING MINI. OP 1-81, 1980, 4pp.; DATAMATION MAG., SEPTEMBER 1980, PP. 217-220.

FURNO, A. L., SAPKO, M. J., LUZIK, S. J., WATSON, R. W. AN IGNITION SUPPRESSION DEVICE FOR COAL CUTTING EQUIPMENT. 1985, 8pp.; CH. IN SAFETY IN MINES RESEARCH, 1985, PP. 661-668.

PATENTS

LIEBMAN, I., CORRY, J., PRO, R. PASSIVE EXPLOSION BARRIER FOR MINES. 1981, 0pp.; U.S. PATENT NO. 4,284,144, AUGUST 18, 1981.

6. FIRES AND EXPLOSIONS
E. MISCELLANEOUS

CONTRACT PUBLICATIONS

BAKER, R. M., NAGY, J., MCDONALD, L. B., WISHMYER, J. (ALLEN CORP. OF AMERICA, JO295035, W. POMROY, TPO, TCRC). AN ANNOTATED BIBLIOGRAPHY OF METAL AND NONMETAL MINE FIRE REPORTS. FINAL REPORT, VOLUME I. OFR 68(1)-, 1980, 64pp.; NTIS: PB/81-223729.

BAKER, R. M., NAGY, J., MCDONALD, L. B., WISHMYER, J. (ALLEN CORP. OF AMERICA, JO295035, W. POMROY, TPO, TCRC). AN ANNOTATED BIBLIOGRAPHY OF METAL AND NONMETAL MINE FIRE REPORTS. VOLUME II. OFR 68(2), 1980, 284pp.; NTIS: PB/81-223737.

BAKER, R. M., NAGY, J., MCDONALD, L. B., WISHMYER, J. (ALLEN CORP. OF AMERICA, JO295035, W. POMROY, TPO, TCRC). AN ANNOTATED BIBLIOGRAPHY OF METAL AND NONMETAL MINE FIRE REPORTS. FINAL REPORT, APPENDIX. OFR 68(3), 1980, 390pp.; NTIS: PB/81-223745.

BOOS, R. T., EGAN, W. D., ELLIOTT, R. A., DEFREEZE, R. K. (BETHLEHEM STEEL CORP, HO123032, PRC). DUAL WAVE LENGTH LIGHT SOURCES. OFR 53-86, 1985, 160pp.; NTIS: PB 86-209483.

CROOKSTON, R. B., ATWOOD, M. T., WILLIAMS, R. E., MCGUIRE, M. D. (TOSCO CORP., JO275001, PRC). AN EVALUATION OF THE FIRE AND EXPLOSION HAZARDS OF OIL SHALE MINING AND PROCESSING, VOLUME 1: ANALYTICAL STUDIES AND ACCIDENT SCENARIOS. OFR 12(1), 1983, 268pp.; NTIS: PB 85-165492.

CROOKSTON, R. B., MCGUIRE, M. D. (TOSCO CORP., JO275001, PRC). AN EVALUATION OF THE FIRE AND EXPLOSION HAZARDS OF OIL SHALE MINING AND PROCESSING, VOLUME 2: DATA SUMMARY OF ANVIL POINTS RAW SHALE WASTE PILE COMBUSTION. OFR 12(2), 1983, 144pp.; NTIS: PB/85-165959.

CROOKSTON, R. B., MCGUIRE, M. D. (TOSCO CORP., JO275001, PRC). AN EVALUATION OF THE FIRE AND EXPLOSION HAZARDS OF OIL SHALE MINING AND PROCESSING, VOLUME 3: OIL SHALE MINE DUST PROGRAM. OFR 12(3)-8, 1983, 74pp.; NTIS: PB/85-165967.

LAIRD, W., BHATT, S., BAJPAYEE, T., ET AL (GATES ENG. CO., JO395060, B. NELSON, TPO, TCRC). A TRAINING PROGRAM FOR FIGHTING SMALL FIRES IN THE MINING INDUSTRY. OFR 179-82, 1982, 89pp.; NTIS: PB/83-170639.

PETTITT, M. R., GIUNTINI, R. E., WESSELS, W. R. (WYLE LABORATORIES, JO395100, R. BARTHOLOMAE, TPO, PRC). FIRE HAZARD CRITERIA FOR NOISE CONTROL PRODUCTS IN UNDERGROUND COAL MINES. OFR 175-8, 1983, 211pp.; NTIS: PB/83-262584.

SHIBE, J. A. (NAT'L BUREAU OF STANDARDS, JO100053,PRC). SYSTEMS APPROACH TO MINE FIRE SAFETY. OFR 35-87, 1987, 144pp.; NTIS: PB 87-227898.

TREUHAFT, M. P., DIAL, B. C. (SOUTHWEST RESEARCH INSTITUTE, JO100006,A, FURNO,TPO,PRC). STUDY OF AIR COMPRESSOR HAZARDS IN UNDERGROUND AND SURFACE MINES. OFR 122-81, 1981, 93pp.; NTIS: PB/82-105164.

IN-HOUSE PUBLICATIONS

BUTANI, S. J., POMROY, W. H. A STATISTICAL ANALYSIS OF METAL AND NONMETAL MINE FIRE INCIDENTS IN THE UNITED STATES FROM 1950 TO 1984. IC 9132, 1987, 41pp.

COURTNEY, W. G., KOST, J., COLINET, J. DUST DEPOSITION IN COAL MINE AIRWAYS. TPR 116, 1982, 15pp.

EDWARDS, J. C., PERLEE, H. E. SUPERHEATED DROP VAPORIZATION: HALON 1301. RI 8658, 1982, 19pp.

EGAN, M. R., LITTON, C. D. WOOD CRIB FIRES IN A VENTILATION TUNNEL. RI 9045, 1986, 18pp.

HERTZBERG, M. A CRITIQUE OF THE DUST EXPLOSIBILITY INDEX: AN ALTERNATIVE FOR ESTIMATING EXPLOSION PROBABILITIES. RI 9095, 1987, 24pp.

KUCHTA, J. M. INVESTIGATION OF FIRE AND EXPLOSION ACCIDENTS IN THE CHEMICAL, MINING, AND FUEL-RELATED INDUSTRIES - A MANUAL. B 680, 1986, 84pp.

LITTON, C. D. GAS EQUILIBRIUM IN SEALED COAL MINES. RI 9031, 1986, 13pp.

LITTON, C. D., DEROSA, M., LI, J. CALCULATING FIRE-THROTTLING OF MINE VENTILATION AIRFLOW. RI 9076, 1987, 21pp.

MCDONALD, L. B., POMROY, W. H. A STATISTICAL ANALYSIS OF COAL MINE FIRE INCIDENTS IN THE UNITED STATES FROM 1950 TO 1977. IC 8830, 1980, 42pp.

NG, D. L., CASHDOLLAR, K. L., HERTZBERG, M., LAZZARA, C. P. ELECTRON MICROSCOPY STUDIES OF EXPLOSION AND FIRE RESIDUES. IC 8936, 1983, 63pp.

PERZAK, F. J., KUBALA, T. A., LAZZARA, C. P. FIRE TESTS OF FIVE-GALLON CONTAINERS USED FOR STORAGE IN UNDERGROUND COAL MINES. RI 8946, 1985, 35pp.

PERZAK, F. J., LAZZARA, C. P., KUBALA, T. A. FIRE TESTS OF RIGID PLASTIC VENTILATION DUCTS. RI 9085, 1987, 16pp.

POMROY, W. H., JOHNSON, G. A. IMPROVED FIRE PROTECTION FOR UNDERGROUND FUEL STORAGE AND FUEL TRANSFER AREAS. IC 9032, 1985, 19pp.

RICHMOND, J. K., PRICE, G. C., SAPKO, M. J., KAWENSKI, E. M. HISTORICAL SUMMARY OF COAL MINE EXPLOSIONS IN THE UNITED STATES, 1959-81. IC 8909, 1983, 53pp.

SAPKO, M. J., WEISS, E. W., WATSON, R. W. SIZE SCALING OF GAS EXPLOSIONS: BRUCETON EXPERIMENTAL MINE VERSUS THE LAKE LYNN MINE. RI 9136, 1987, 23pp.

JOURNAL ARTICLES & OUTSIDE PUBLICATIONS

CASHDOLLAR, K. L., HERTZBERG, M. INTRODUCTION TO DUST EXPLOSIONS. 1987, 28pp.; CH. IN INDUSTRIAL DUST EXPLOSIONS. ST 958, ASTM, 1987, PP. 5-32.

CASHDOLLAR, K. L., SAPKO, M. J., WEISS, E. S., HERTZBERG, M. LABORATORY AND MINE DUST EXPLOSION RESEARCH AT THE BUREAU OF MINES. 1987, 17pp.; CH. IN INDUSTRIAL DUST EXPLOSIONS. STP 958, ASTM, 1987, PP. 107-123.

CECALA, A. B., O'GREEN, J., WATSON, R., JANKOWSKI, R. A. REDUCING LONGWALL FACE IGNITIONS. OP 29-85, 1985, 3pp.; WORLD MIN. EQUIP., V. 9, NO. 1, JAN. 1985, PP. 44-46.

COURTNEY, W. G. DUST CONTROL. 1982, 25pp.; CHAPTER IN "UNDERGROUND MINING METHODS HANDBOOK.", AIME, NEW YORK, NY, 1982, PP. 1687-1711.

DRISCOLL, T. J. COATINGS ON ALUMINUM TO REDUCE INCENDIVITY IN METHANE-AIR MIXTURES. OP 102-87, 1987, 8pp.; TRANS. SOC. MIN. ENG. AIME, V. 280, 1987, PP. 1869-1876.

HERTZBERG, MARTIN, NG, DANIEL L. A MICROSCOPIC AND KINETIC STUDY OF COAL PARTICLE DEVOLATILIZATION IN A LASER BEAM. OP 107-87, 1987, 22pp.; PUBL. IN "FUND. OF PHYSICAL CHEM. OF PULVERIZED COAL COMP." ADV. SCI. INST., SER. E, NO. 137.

LEE, C. K., HWANG, C. C., SINGER, J. M., CHAIKEN, R. F. INFLUENCE OF PASSAGEWAY FIRES ON VENTILATION FLOWS. OP 111-84, 1980, 7pp.; MINE VENTILATION CONGRESS, RENO, NV, NOV. 4-8, 1979. SOC. MIN. ENG. AIME, NY, 1980, PP. 448-454.

NG, D. L., LAZZARA, C. P. FIRE ENDURANCE OF MINE STOPPINGS. OP 124-87, 1987, 4pp.; PROC. EAST. SEC., THE COMBUSTION INSTITUTE/NBC, ANN. CONF. ON FIRE RES. 1987, PP. 100-1-100-4.

NG, D. L., SAPKO, M. J., FURNO, A. L., PRO, R. COAL DUST AND GAS EXPLOSION SUPPRESSION. 1987, 14pp.; CH. IN INDUSTRIAL DUST EXPLOSIONS, STP 958, ASTM, 1987, PP. 138-151.

PERZAK, F. J., LAZZARA, C. P., KUBALA, T. FIRE TESTS OF RIGID PLASTIC VENTILATION DUCTS. 1987, 4pp.; PROC. EAST. SEC., THE COMBUSTION INSTITUTE/NBC ANN. CONF. ON FIRE RES., 1987, PP. 101-1-101-4.

SAPKO, M., HERTZBERG, M., WATSON, R., CASHDOLLAR, K. DUST EXPLOSION SIZE SCALING. 1987, 17pp.; PROC. SHENYANG INT'L SYMP. ON DUST EXPLOSIONS, 1987, PP. 271-287.

TIMKO, R. J., DERICK, R. L., THIMONS, E. D. ANALYSIS OF A FIRE IN A COLORADO COAL MINE - A CASE STUDY. 1987, 9pp.; PROC. 3RD MINE VENTILATION SYMP., 1987, PP. 444-452.

Recent Presentations and Publications of the Fires and Explosions Group

Presentations and Publications

1. "Flammability Limit Measurements for Dusts and Gases: Ignition Energy Requirements and Pressure Dependencies" by M. Hertzberg, proceedings of 21st Symposium on Combustion, pp. 303-313, 1986.
2. "Volatility Model for Coal Dust Flame Propagation and Extinguishment" by M. Hertzberg, proceedings of 21st Symposium on Combustion, pp 325-333, 1986.
3. "Prevention of Frictional Ignition with Ripper-Type Continuous Mining Machines Using Water Sprays" by W. G. Courtney, proceedings of 3rd Mine Ventilation Symposium, State College, PA, Oct. 12-14, 1987.
4. "Explosibility of Float Coal Dust Distributed Over a Coal-Rock Dust Substratum" by M. J. Sapko, 22nd International Conference of Safety in Mines Research Institute, Beijing, China, Nov. 2-6, 1987.
5. "Optical Remote Methanometer" by C. D. Litton, 22nd International Conference of Safety in Mines Research Institute, Beijing, China, Nov. 2-6, 1987.
6. "Spontaneous Combustion Potential of Coal" by C. P. Lazzara, Symposium on Spontaneous Combustion of Coal, Alberta, Canada, Nov. 13, 1987.
7. "Industrial Dust Explosions" ed., K. L. Cashdollar, American Society for Testing and Materials, Philadelphia, PA, Dec. 1987.
8. "Thermal Autoignition Temperatures from the 1.2-L Furnace and Their Use in Evaluating the Explosion Potential of Dusts" by R. S. Conti, Industrial Dust Explosions, STP 958, ASTM, pp. 45-59, Philadelphia, PA, Dec. 1987.
9. "Remote Measurement of Methane" by C. D. Litton, Open Industry Briefing IEEE, Minneapolis, MN, April 1, 1988.
10. "Diesel-Discriminating Detector" by C. D. Litton, Open Industry Meeting IEEE, Minneapolis, MN, April 1, 1988.

Presentations and Publications (Cont'd)

11. "Overview of USBM-ETI Blasting Research Program" by M. J. Sapko, Staff of Explosive Technologies International, Canada, April 12, 1988.
12. "Overview on Oil Shale Blasting Research" by M. J. Sapko, Colorado Mining Assn., Colorado, Apr. 20, 1988.
13. "Exposition Area for the Rock Dust Meter" by M. J. Sapko, American Mining Congress Mine Expo Internat'l, Chicago, IL, April 25-27, 1988.
14. "Preferred Explosives for Blasting in the Presence of Combustible Dusts" by M. J. Sapko, proceedings of Canadian Institute of Mining and Metallurgy, Canada, May 9-11, 1988.
15. "Prevention of Oil Shale Dust Explosions" by M. Hertzberg, 21st Oil Shale Symposium, Beijing, China, May 16-19, 1988.
16. "Preferred Explosives for Blasting in Oil Shale Mines" by E. S. Weiss, 21st Oil Shale Symposium, Beijing, China, May 16-19, 1988.
17. "Optical Dust Deposition Meter" by M. J. Sapko, proceedings 1988 IEEE Mining Industry Technical Conference, Pittsburgh, PA, June 9-11, 1988.
18. "Overview of Explosive Development for Blasting in Gassy Oil Shale Mines" by M. J. Sapko, Colorado Mining Association, Colorado, Sept. 1988.
19. "Mine Fire Detection Systems: A Primer" by C. D. Litton; "Diesel-Discriminating Fire Detector" by C. D. Litton; "Emission Products from Wood Crib and Transformer Fluid Fires" by M. R. Egan; "Utilization of Smoke Properties for Predicting Relative Toxicity of Combustion Products" by M. I. DeRosa, proceedings, Denver, CO; Detroit, MI; Spokane, WA; Las Vegas, NV; October 1988.
20. "Analog Optical Rock Dust Meter" by T. Woods, M. J. Sapko, H. Perlee, IEEE Annual Meeting, Pittsburgh, PA, Oct. 2-7, 1988.

Presentations and Publications (Con't)

21. "Selective Diffusional Demixing: Occurrence and Size of Cellular Flames" by M. Hertzberg, University of California, Oct. 11, 1988.
22. "The Mechanism of Flame Propagation in Dust Explosions" by M. Hertzberg, Stanford University, CA, Oct. 12, 1988.
23. "Devolatilization Wave Structures and Propagation Rates for the Pyrolysis of Coals, Polymethylmethacrylate and Ammonium Perchlorate at Combustion Level Heat Fluxes" by M. Hertzberg, The Combustion Institute Western States Section Meeting, Dana Point, CA, Oct. 17-18, 1988.

APPENDIX C
FIRE TRAINING GALLERY DATA
SPECIFICATIONS AND COST

CAPITAL COST ESTIMATES -
FURNISHINGS AND FITTINGS

	<u>\$</u>
a) <u>Entrance Hall:</u>	
3 x Coat and boot racks, \$289 each	876
2 x 2 seat/table reception sets \$470 each	940

	1,807
b) <u>Medical Room:</u>	
3 x Thermometer	21
1 x Automatic Digital Blood Pressure Monitor	354
1 x Weight scale	86
1 x Utility light	79
1 x Screen	67
1 x Treatment chair	402
+ Wash Basin	23
1 x Supply Cabinet	670
1 x Sani-can peddle bin	30
1 x Combination Stretcher chair	751
1 x Examination Couch	325
1 x Maxi first aid station	206
1 x Fire and burn kit	71
1 x Desk	300
1 x Chair	55
1 x Reviver MMV Maximum + Accessories	980
Assortment of splints and Miscellaneous	580

	5,000
c) <u>Washroom and Dry:</u>	
Drying Racks	600
Towel Dispensers Mirrors + Sundry fittings	400

	1,000

		<u>\$</u>
d)	<u>Control Room:</u> (See Appendix 'C' - Control System)	
	2 x Loud speaker/telephone/switchboard	4,960
	1 x Alarm bell	165
	2 x Chairs - plastic/metal	50
	1 x Digital clock/calendar	25
	Miscellaneous	470

		5,670
e)	<u>Instruction Room:</u>	
	25 chairs @ \$52	1,300
	9 Tables @ \$317	2,853
	Chalk boards 3 @ \$50	150
	Flip chart board @ \$150	93
	2 Notice board @ \$25	50
	Projector screen	200
	Video apparatus	1,200
	O/H projector	624
	Slide projector	500
	Film projector	1,000
	2 Cupboards (steel) \$400 each	800

		8,770
f)	<u>Inside Drill Area:</u>	
	Display, Writing Boards and Chalkboards	300
	3 Work tables @ \$159	478
	12 Seats @ \$51	612
	2 Loud speaker phones	1,400
	Alarm bell	100
	Electric wall clock	100
	3 Storage cupboards @ \$400	1,200

		4,190
		<u>\$</u>
g)	<u>Instructor's Office:</u>	
	2 Desks @ \$501	1,002
	3 Chairs 2 @ \$678 + 1 @ \$530	1,886
	2 Filing Cabinets (legal size 4 drawer)	906
	2 Cupboards (Low) @ \$422	844
	1 Cupboard (High)	400
	1 Writing board	35
	1 Book shelf	200
	2 Waste paper bins	17

		5,290

h) Chief's Office:

1 Desk	624
1 Desk chair	678
3 Visitors chairs @ \$530	1,590
1 Book shelf	245
1 Credenza	663
1 Filing Cabinet	570
Waste paper bin	9
Notice board	43
Conference table	628

	5,050

i) Reception Area:

Secretarial Desk	666
Desk top P.C. + Printer + Accessories	3,000
Dictating machine	600
Waste paper bin	9
Fining cabinet	453
Cupboard	528
Table	317
Coffee Cabinet	159
Coffee Machine	200
Coat trees, 2 @ \$67	134
Photocopier and stand	1,277

	7,343

j) Janitor's Room:

Brooms, buckets, mops, industrial vacuum cleaner	1,390

k) <u>Store and Workshop:</u>	<u>\$</u>
Shelving	2,800
2 Steel tables	650
2 Work benches	1,100
Vice	80
Electric drill + stand	420
Tools	600
Card index - equipment register	40
Cabinet	400
Portable drill	100
Haskel CO ₂ pump (See Appendix C)	12,400

	18,590

l) <u>Outside Practice Yard:</u>	
Cement, wall and concrete structures	31,600
Steel arches and beams	8,000
Wood Lagging and Covering material	1,000
Compressor, conveyor drive and cables, are items scrapped from mines - no value assigned	-
Gas pipes and butane bottles	300
Water jet targets and Miscellaneous	1,100

	42,000

m) Hot and Humid Chamber:

It is assumed that exercise apparatus will be installed,

Variable speed Treadmill	5,200
Ergometer/Cyclometer cycle	1,100

Note: both above available
Quinton Instrument Co.
Seattle, Washington U.S.A

6,300

n) <u>'Mine' Galleries:</u>	<u>\$</u>
Emergency pull wires	1,400
Painting and Simulation of U. Grd.	2,100
Steel arches 30 @ \$400	12,000
Steel beams 90 @ \$200	18,000
Pipes and Water ranges etc.	3,300
Lighting units and cables	1,800
Fire extinguishers & hoses & equipment	6,400

It is assumed that all other materials
for mine simulation will be available
from scrap and rejects of the mines,
i.e.

Auxil. fan and tubes

Used timber

Steel bars

Mine telephones etc.

Total

45,000

CAPITAL COST ESTIMATES

TRAINING EQUIPMENT AND INITIAL SUPPLIES

<u>ITEMS</u>	<u>\$</u>
Instruments (Anemometer, step watch, Hygrometers	450
Extinguishers, Dry powder	2,300
Water/gas	700
CO ₂ Portable	1,500
Foam	950
Smoke generators, 2 x Genie Mk. V	2,700
2 x Fire Simulators, (Made at mine)	100
2 x Fire baskets, 2 cuft. cap. for burning paper, wood, rags	50
Hoses, accessories and fittings	12,300
Nozzles and Water curtain nozzles	470
Gallery notices and signs	500
Protective waterproof clothing - suits	8,250
- boots, gloves, goggles, hard hats	1,620
Training aids: Books	600
Films	460
Slides	50
Sound effects: Tape recorder/player, amplifier, cassettes, etc.	1,000
Hand Tools	600
Turnkey and Hose winding machines, c/w cleaning devises and swaging tools	600
Initial spares and supplies stock:	
Electrical - lights and fittings	300
Extinguisher fillings + fittings	1,650
Hose couplings	160
Instructors' protective clothing	590

Total Training Equipment and Initial Supplies.	37,900

APPENDIX D
PROPOSED FIRE-FIGHTING TRAINING GALLERY
PHALEN SITE

Nova - Scotia Mine Fire Project - Stage 3 - 30-1-89

Mine Fire Training Gallery - Hot and Humid Chamber

Purpose of Chamber

- To give trainees -
- Experience of heat and humidity
 - Acclimatisation to heat and humidity
 - Lessons in suitable dress for hot conditions
 - Resting and comfort experience
 - Progressing increase in activity to walking and moderate physical effort.
 - Experience of varying activity levels on treadmill and ergometer (cycle type)
 - experience of physical tasks - lifting, carrying, sawing, shovelling etc.
 - simple construction and assembly tasks
 - These experiences are conducted in a range of visibilities from clear to DENSE SMOKE.

Limits of Exposure and precautions

1. The time of exposure and task level is GRADUALLY increased, with training, but should not exceed these exposure times

	80°	90°	100°	110°	120°	Dry bulb Temp °F
	max exposure time (minutes)					
80°	90	75	60	45	20	
90°	-	45	40	35	15	
100°	-	-	30	10	5	
110°	-	-	-	Exposure		
120° F	-	-	-	- Harmful		
Wet bulb Temp.						

2. The trainees must be continuously observed during hot chamber experience - usually from the control room window

- 3 The emergency hall wire and other safety and first Aid equipment must be regularly checked pending hot chamber use
- 4 If any special trainings are given in extremely hot or humid conditions, or if trainees are undertaking tests of equipment, techniques or physical condition or tolerance then the Medical room shall be staffed by a Doctor and/or a Nurse

Dimensions

The chamber shall measure, internally, approximately 10 M long by 4 M wide by 2.5 M high.

Allowing for the thickness of the insulation and hot air ducts, with access, this means that the true ceiling height of the first floor of the building structure will need to be approximately 3.25 M which will be a factor determining the overall height of the building

Environmental Limits

It is proposed that any condition within the following range shall be provided and maintained uniformly throughout the chamber :-

	Minimum	Maximum	Tolerance
Dry bulb Temp	Ambient	100°F	± 2°F
Wet bulb Temp	Ambient	100°F	± 2°F
Humidity	Ambient	100%	± 2%

The maximum unregulated dry bulb temperature that the chamber shall be capable of providing shall be 120°F

It is not proposed to apply any air refrigeration or drying to the chamber, although this facility could be added later if required.

Construction

The chamber will be built within the normal brick / block room shell and will have thick insulation on all 6 sides. The interior walls are to be of composite boarding having a strong impact and wear resistant skin.

The floor should be finished in quarry tiles with insulation blocks beneath (important)

If possible all edges and corners should be rounded to facilitate cleaning.

The entrance from the main corridor should be by double⁽²⁾ air lock, Cyke doors, and the entrance from the long wall gallery by a massive pit Cyke door. All doors should be well fitting and heavily heat insulated.

There must be one observation window from the control room, and possibly 3 observation windows from the corridor. The windows should be small in size eg. $0.54 \times 0.75 \text{ M}$ and ~~triple~~ triple glazed to retain heat.

Fittings will include strip lights (mainline existing) ~~light~~ loudspeaker system to control, 4 monitoring points and a power point.

Equipment will include treadmill and ergometer devices, and cath equipment eg. Wood blocks

Insulation

Insulation is required on all 6 sides of the chamber and around the hot air ducts and in the Plenum room. The material requires to be carefully chosen for adequacy, resistivity and suitability

belly Perene Station, an 8" thick layer of Fibreglass around the sides, but other suitable materials are available eg "Bestobell" (in U.K.)

Plenum Air Conditioning System.

At belly, this was supplied by the Packaged Air Conditioning Equipment Ltd (PACE) of Dockfield Industrial Estate Shipley, West Yorks U.K. BD 17 7SX Telex 517742 Fax 0274 531107. Details of their outline spec & quote are enclosed with my comments. I am asking them to supply schematic diagrams & brochures.

The airflow system is a recirculating one with air drawn from the top of the chamber, passed through heating coils (from the building hot water supply - obtained from the Stalen Mine in our case hopefully) and blown back into the 2 inlets at the floor of the chamber (at diametrically opposite corners to encourage circulation and mixing - an important point). I think about 80% of the airflow will be re-circulated & 20% will be fresh air intake, with 20% of the old air 'dumped'. I will check on this.

The spec includes for air filters, but these should be removed, I think, when smoke is used in the chamber training session, otherwise the filters will take it straight out!

The humidifier is by VAPAC HUMIDIFIERS LTD. of Edenbridge, Kent U.K. and this consists of a small flow of water being converted to steam by an electrical heater and blown into the ducted air stream by a fan.

I ~~am~~ will find out if PACE have a Canadian Agent, but I know VAPAC have one - "National Environment Products Ltd" - Montreal.

The level of heat and water vapour added to the air is automatically controlled by the monitoring system, see below.

X

The price £6209 for the heater & humidifying heater system seems quite reasonable to me.

Instrumentation Monitoring and Control

The suppliers of this equipment for Jolly were Hatchwell Control Systems Ltd PO Box 57 Farnham Rd. Slough Berkshire U.K. Tel 0753 824078 Telex 848186. Full details of proposals are enclosed.

The system will respond to the average reading of 4 sets of Temperature and humidity sensors installed on the wall of the chamber, two on either side, one near floor and ^{the other at} roof level. a fifth sensor will be placed in the inlet duct to warn if the temperature suddenly drops, as in fault condition.

The readings of temperature and humidity, the settings, alarm and control will be displayed & operated from the adjacent Control Room.

The sensor will be recessed into the wall of the chamber to minimise the chance of damage by activity of the trainees.

The price quoted is £8626 including commissioning and mini computer (IBM compatible)

They offer the option of their BAS 2000 Building Management System for an extra £18,536.

I would NOT recommend this unless it is required to extend the system to monitor all the heating and other services in the building, or the chamber is to be used for testing and research when the print out and computerised control facility would be a valuable.

Note that Hatchwell have an agent in Canada - Windeler Controls, Agincourt, Ontario.

Operating the System

The system is capable of operation by any of the Training Gallery Staff, and with training and familiarisation will quickly become highly proficient at it.

It will take much time and trouble to commission, adjust and calibrate the Chamber its heating systems and controls in the first instance, but subsequently there will be little difficulty in maintaining performance and accuracy.

The chamber will take about 2 hrs to attain the prescribed condition, and to stabilise at this condition so the daily procedure is for the system to be switched on first thing in the morning in readiness for the arrival of the trainees.

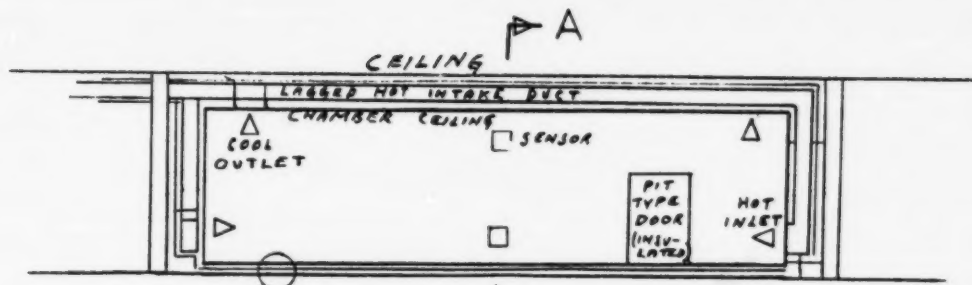
Conclusion

The design of Chamber proposed includes the best of "State of the Art" Technology. It will be better than for any similar installation / establishment World Wide, but will not match the environmental galleries at Research Institutes etc.

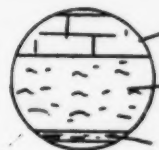
The clients will be quick to recognise the use of the Chamber for purposes far beyond the original & principal purpose: - Training of mine rescue teams, testing of equipment etc. and I am convinced it will become a valuable asset to progress in the Mining World of Eastern Canada.

L. V. Jolly
30.1.89.

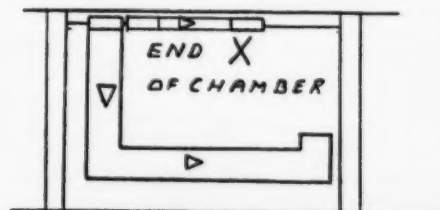
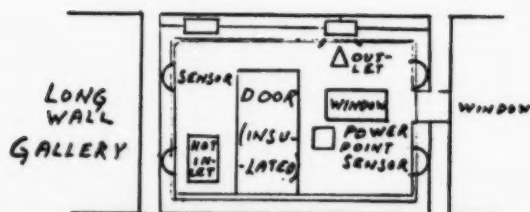
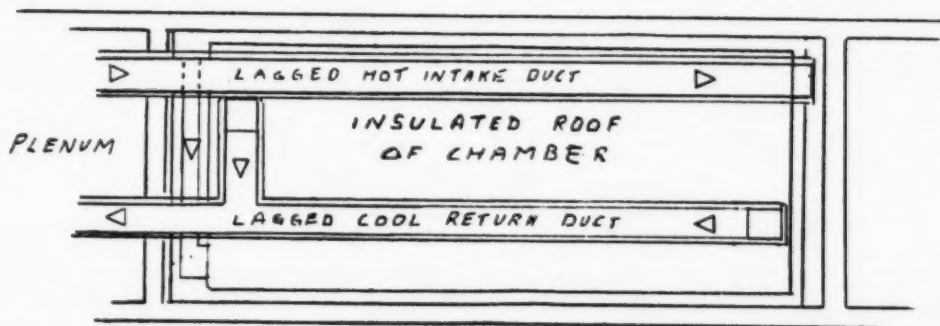
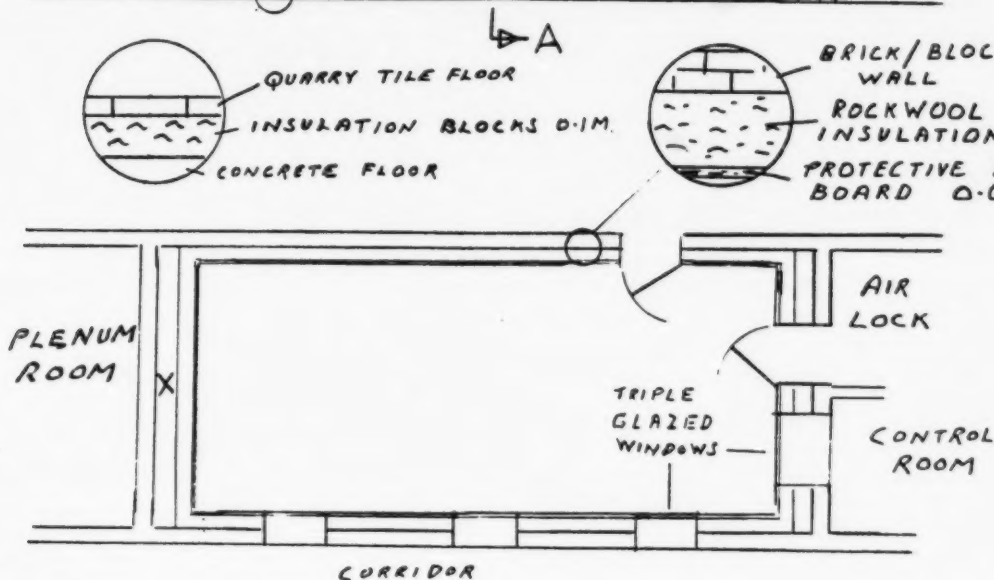
CHAMBER



QUARRY TILE FLOOR
INSULATION BLOCKS 0.1M.
CONCRETE FLOOR



BRICK/BLOCK WALL
ROCKWOOL INSULATION 0.2M
PROTECTIVE RESIN BOARD 0.02M



SECTION A-A

SCALE 1-100

North Hylton Road • Sunderland, England SR5 3JD

Mr. G. Jolliffe
141 Bantry Road
Bessecarr
Doncaster
Yorks. DN4 7AH

QUOTATION No. 100051
OUR REF: GP/JVS
YOUR REF:
DATE: 22nd February, 1989

Dear Sirs,

Thank you for your enquiry dated

We have pleasure in submitting our quotation and look forward to receiving your further instructions.

Yours faithfully

HASKEL ENERGY SYSTEMS LIMITED

Graham Pinkerton
Applications Engineer

Thank you for your enquiry, we are pleased to offer our quotation for the supply of a Carbon Dioxide Charging Panel.

<u>Part No.</u>	<u>Description</u>	<u>Unit Price</u> £.p
SAT 13899	Haskel Air Driven CO ₂ Charging Panel consisting of a Haskel Model DSF-B15 pump mounted in a stove enamelled wall mounting panel. Included are 4" dia. 0-2000 psi pressure gauges for inlet and outlet circuits, high pressure stop and vent valves, air controls, high pressure pipework, high pressure flexible hoses for charging and supply. Approximate panel dimensions 32" x 20" x 9" deep.	3510.00

Prices : Ex-Works, Packing, Carriage and VAT Extra
Delivery : 6 / 8 Weeks From Receipt of Order
Payment : Nett Cash 30 Days From Date Of Invoice Subject To Satisfactory Credit Being Established

NOTE :- This pump requires a compressed air supply, maximum demand about 100 C.F.M. at 100 P.S.I. The compressed air could possibly be obtained, piped from the pit or from a small tank mounted

STANDARD CONDITIONS OF SALE - SEE OVERLEAF
REGD. ENGLAND 1278832

compressor; cost
approx £ 3000

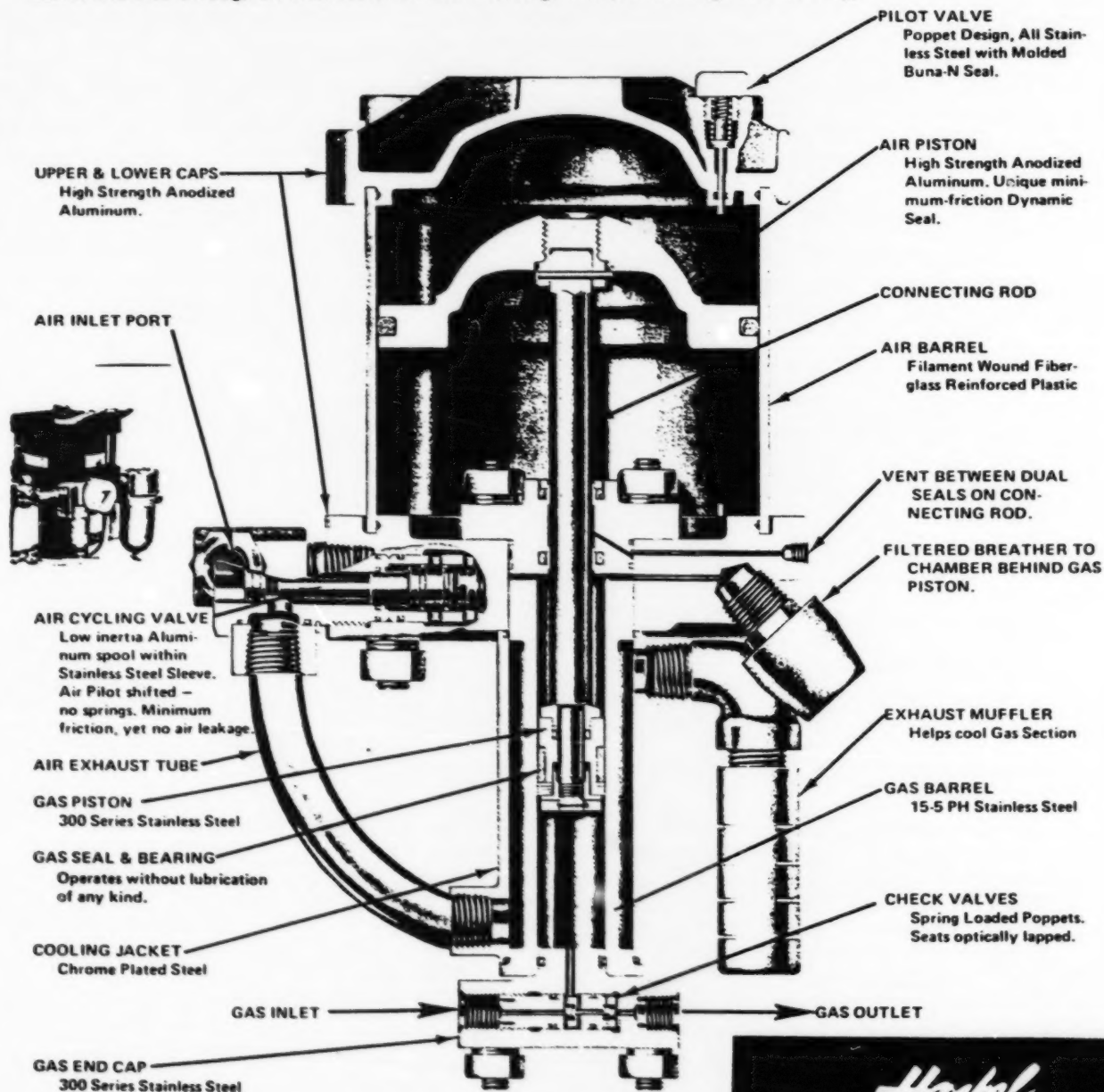
CONTAMINANT — FREE AIR DRIVEN GAS BOOSTERS

General Description

Haskel Gas Boosters consist of a large area reciprocating air drive piston directly coupled by a connecting rod to a small area gas piston. The gas piston operates in a high pressure gas barrel section. Each gas barrel end cap contains high pressure inlet and outlet check valves. The air drive section includes a cycling spool and pilot valves that provide continuous reciprocating action when air is supplied to the air drive inlet.

Isolation of the gas compression chambers from the air drive section is provided by three sets of dynamic seals. The intervening two chambers are vented to atmosphere. This design prevents air drive contamination from entering the gas stream.

Cooling is provided by routing the cold exhausted drive air through an individual jacket surrounding the gas barrel and also through an intercooler on the interstage line (of two stage models only).



APPROX HEIGHT 14"



HOWDEN SIROCCO



Howden Sirocco Limited - Heavy Machines Division

Suite 4
Kirkgate Commercial Centre
Chantry Bridge
Wakefield WF1 5DL West Yorkshire
Telephone: (0924) 384369 Telex: 556308 Fax: 0924 384634

A Howden Group Company

SD/JAD

14th February 1989

Mr. G.V. Jolliffe
41 Bawtry Road
Bessacar
Doncaster
South Yorkshire. DN4 7AH

Dear Gordon

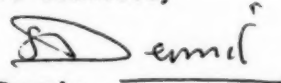
NOVA SCOTIA MINING - GALLERY FAN

Further to our recent telephone conversation I attach Data Sheet, Performance Curve and Dimension Sheet covering a 1 metre diameter Axial Flow Fan to handle 20,000 cfm against 1 inch water gauge.

You will note our offer excludes the switchgear and two speed Controller but if you allow a budget figure of £200 to cover a starter with 2 sets of overloads and push button controls this should suffice.

Trusting the enclosures are sufficient for your requirements.

Yours sincerely



S. Dennis
Howden Sirocco Limited
Heavy Machines Division
Wakefield Office

Enc.



HOWDEN SIROCCO

A.D.C. FAN DIVISION

Strathclyde House, Green Man Lane
Farnborough, Middlesex TW14 0PZ
Tel: 01-890-9489
Telex: 923045
Fax: 01-890-5807

Howden Sirocco Limited
Heavy Machines Division
Suite 4
Kirkgate Commercial Centre
Chantry Bridge
Wakefield
WF1 5JQ

Your Ref 118 1030 CHAL. BY H/DAM OFFICE

Our Ref L/10/00749

Job at COAL MINE TRAINING CENTRE, CANADA

Attention of MR S DENNIS

Date 6.2.89

Prepared by W HOBBS

subject to our General Terms and Conditions of sale which are enclosed herewith.

Identification or Your Ref/Item No.			
Our Product/Item No.			
Fan Type	Axial	<u>COMMENTS BY G.V. JOLLIFFE</u>	
Impeller Type	C6		
Blade Angle	22		
Size	1000		
Casing or Arrgt.	Long		
Bearings	-		
Finish	Hammerite		
Fan r.p.m.	1740/870	<u>NOTE: TWO SPEED FAN</u> high flow 20,000 cfm, low flow 10,000 cfm. This is high, but it could be reduced by fitting a silencer or by using a turn speed, lower speed motor without losing performance. but at extra cost for the special motor or silencer. The noise is rated at 1740 r.p.m. at 870 r.p.m. the noise would only be a fraction of the quoted figure and would be no problem.	
Volume flow cfm	20,000/10,000		
Static w. g. H ₂ O ins	1.0/0.25		
Temp °C	20		
Altitude m or mm Hg.	-		
Fan kW at 20°C 762 mm Hg.	5.8/0.725		
Fan kW at Temp & Baro	-		
Decibel rating dB/dBW	87 - 106		
Motor Type	TEFV IP54 to CSA Requirements (Metric Design)		
Motor kW	7.5/1.9		
Motor Speed	1740/870		
Motor ~~Mounting~~ Frame Size	D160M		
Electrical Supply	550 - 3 - 60		
Extras. Special Provisions			
Backdraught Damper (Gravity operated butterfly type)	£ 822	not illustrated	
Mounting Feet	£ 50		
Flex Connections (Sleeve, 2 Bands, 1 Angle Ring, Fixings)	£ 133 x 1		
Mating Flange	£ 76 x 1		
Anti-Vib Mountings	£ 36		
Inlet Cone & Guard	£ 166	not illustrated	
Number off	1		
Price each Excl extras	£ 1229.00		
Discount	Nett		
Price each Net Incl extras	£ 2512.00	Very reasonable.	
Total Nett	£ 2512.00		
Terms of Sale	Ex Works Glasgow Packed For Shipment		
Terms of Payment	Nett 30 Days/Invoice		
Delivery period in working weeks	12		
Remarks	1. Standard Fan - No special features included 2. Fan capable of 100% duty in reverse mode 3. Controller/Switch Gear excluded <u>NOTE</u>		

STANAX

1000/C/6

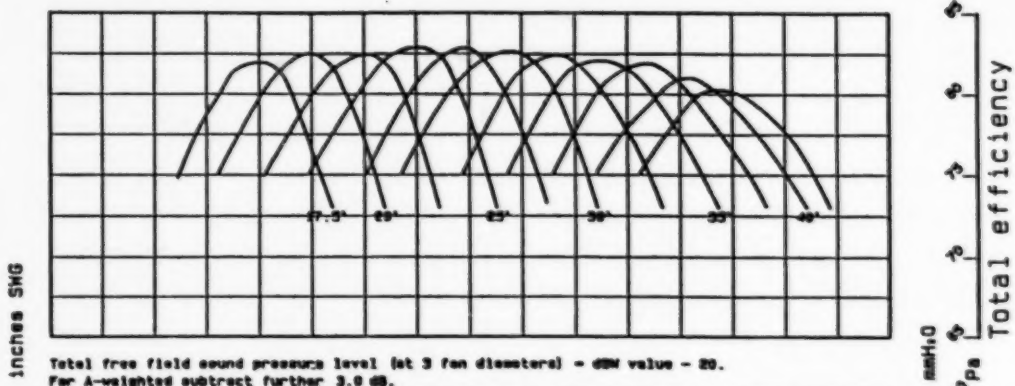
Outlet Area 0.785 m²
Tip Speed 91.1 m/sec
Density 1.2 kg/m³

1740 Rev/min

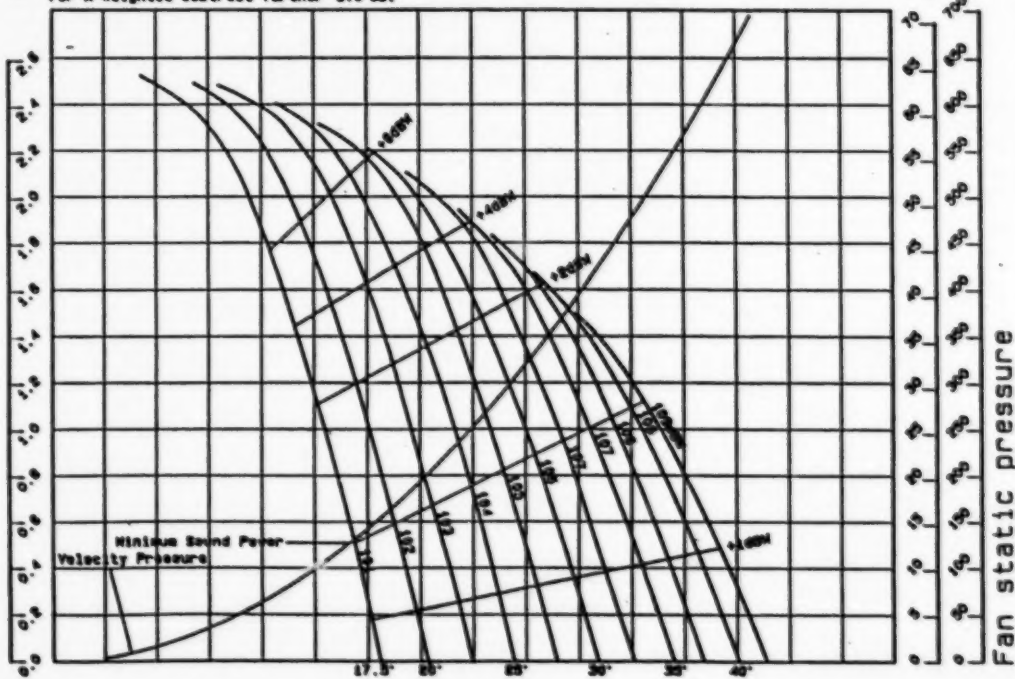
Blade angle (deg)	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5
Max impeller power (kW)	5.329	6.856	7.991	9.764	11.54	13.32	15.09	17.31	19.53	21.75	24.41

To obtain sound spectrum levels subtract tabulated constants from dBM value at duty point.

Octave band mid-frequency (Hz)	63	125	250	500	1k	2k	4k	8k
In Duct L _w (dBM)	-11	-8	-6	-5	-7	-10	-15	-21
Free Field L _p (dB)	-33	-30	-27	-25	-27	-30	-35	-41

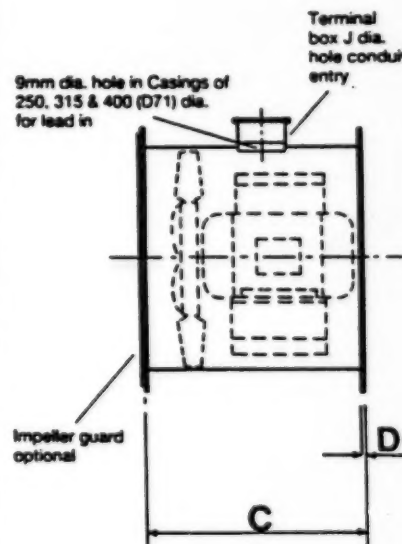
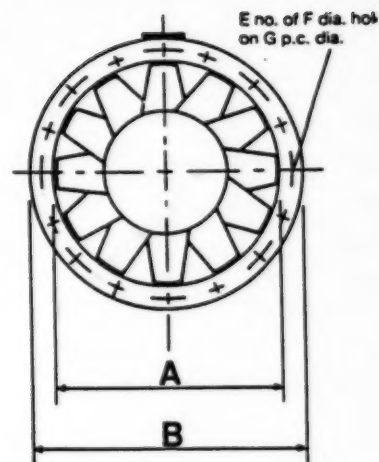


Total free field sound pressure level (at 3 fan diameters) = dBM value - 20.
For A-weighted subtract further 3.0 dB.



Volume flow

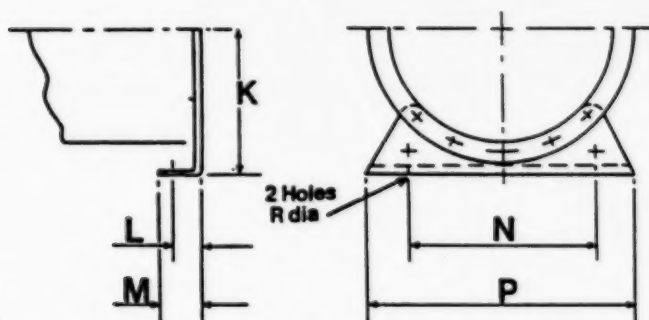
Dia. of Unit	Motor Frame	A	B	C	D	E	F	G	J	Wt. (kg)
250	D71	250	300	470	2	4	10	280	—	12.7
315	D71	315	375	470	2	8	10	355	—	14
	D80	315	375	470	2	8	10	355	—	16
400	D71	400	490	470	2	8	12	450	21	18.6
	D80	400	490	470	2	8	12	450	21	26
	D90S	400	490	470	2	8	12	450	21	29
	D90L	400	490	470	2	8	12	450	21	31
500	D71	500	600	470	2.5	12	12	560	21	32.2
	D80	500	600	470	2.5	12	12	560	21	39.8
	D90S	500	600	470	2.5	12	12	560	21	47.2
	D90L	500	600	470	2.5	12	12	560	21	50
	D100L	500	600	590	2.5	12	12	560	21	56.8
	D112M	500	600	590	2.5	12	12	560	26	68.5
	D132S	500	600	590	2.5	12	12	560	26	85
560	D80	560	660	470	3	12	12	620	21	49.3
	D90S	560	660	470	3	12	12	620	21	53
	D90L	560	660	470	3	12	12	620	21	56.3
	D100L	560	660	590	3	12	12	620	21	66.5
	D112M	560	660	590	3	12	12	620	26	78.7
	D132S	560	660	590	3	12	12	620	26	113.2
630	D80	630	730	470	3	12	12	690	21	58.3
	D90S	630	730	470	3	12	12	690	21	60
	D90L	630	730	470	3	12	12	690	21	63.5
	D100L	630	730	590	3	12	12	690	21	78.6
	D112M	630	730	590	3	12	12	690	26	89.3
	D132S	630	730	590	3	12	12	690	26	107
	D132M	630	730	590	3	12	12	690	26	115
710	D80	710	810	470	3	16	12	770	21	66.6
	D90S	710	810	470	3	16	12	770	21	69.6
	D90L	710	810	470	3	16	12	770	21	71.7
	D100L	710	810	590	3	16	12	770	21	81.3
	D112M	710	810	590	3	16	12	770	26	91.5
	D132S	710	810	590	3	16	12	770	26	104.5
	D132M	710	810	590	3	16	12	770	26	112.5
800	D90S	800	900	470	4	16	12	860	21	101
	D90L	800	900	470	4	16	12	860	21	104
	D100L	800	900	590	4	16	12	860	21	112.5
	D112M	800	900	590	4	16	12	860	26	124.5
	D132S	800	900	590	4	16	12	860	26	141
	D132M	800	900	590	4	16	12	860	26	149
	D160M	800	900	840	4	16	12	860	26	183
	D160L	800	900	840	4	16	12	860	26	202
1000	D90S	1000	1120	490	4	16	15	1070	33	182.5
	D90L	1000	1120	490	4	16	15	1070	33	184.5
	D100L	1000	1120	610	4	16	15	1070	33	193
	D112M	1000	1120	610	4	16	15	1070	33	202
	D132S	1000	1120	610	4	16	15	1070	33	218
	D132M	1000	1120	610	4	16	15	1070	33	243
	D160M	1000	1120	860	4	16	15	1070	33	292
	D160L	1000	1120	860	4	16	15	1070	33	299
	D180M	1000	1120	860	4	16	15	1070	33	360
	D180L	1000	1120	860	4	16	15	1070	33	371
	D200L	1000	1120	960	4	16	15	1070	33	422
	D225S	1000	1120	1220	4	16	15	1070	33	477



The following accessories are available at extra cost:

11.1 Mounting Feet

Mounting feet (Table 6) can be fitted to the casing in any configuration to suit the installation. Dimensional data is given below.



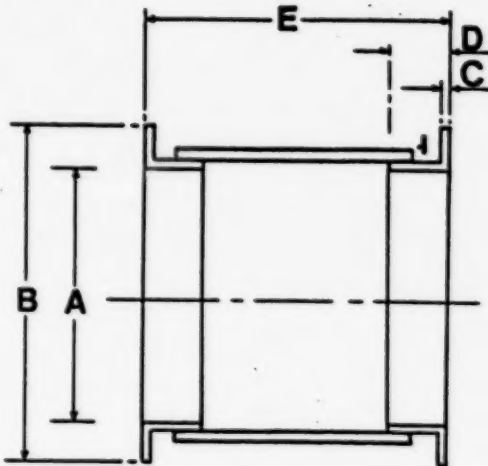
Diameter of Unit	K	L	M	N	P	R	Weight/Pair (kg)
250	175	15	25	300	330	10	1.5
315	215	20	30	370	400	10	2.5
400	270	25	45	450	490	12	3.5
500	325	30	50	550	590	12	4.5
560	355	30	50	610	650	12	5.0
630	390	30	50	680	720	12	6.0
710	430	30	50	760	800	12	7.0
800	475	30	50	850	890	12	13.5
1000	585	35	60	1050	1100	15	19.5

ALL DIMENSIONS IN MILLIMETRES.

Table 6. Mounting Feet - Dimensions and Weights

11.2 Matching Flanges and Flexible Connection

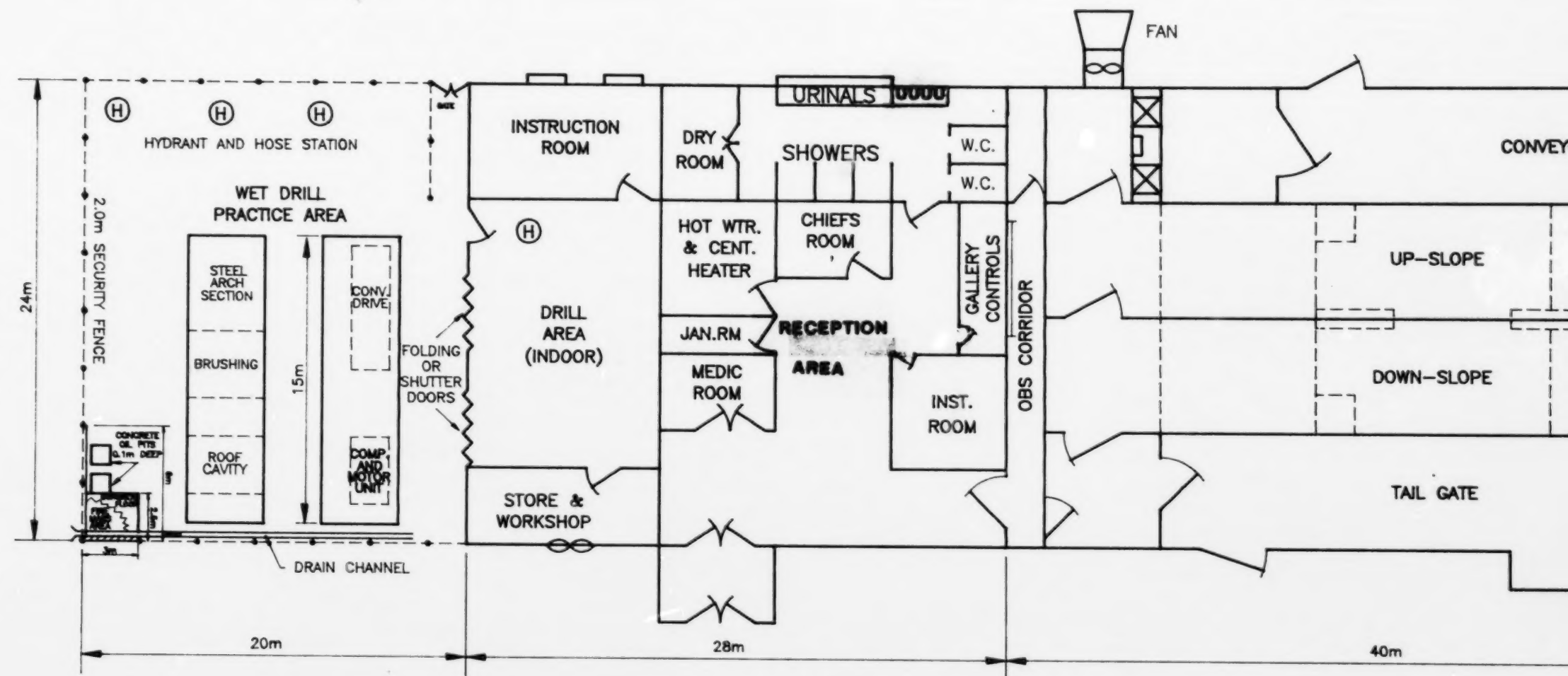
Matching Flanges (Table 7) are drilled to match the fan and are available for all sizes to facilitate the installation of a flexible connection.



Diameter of Unit	A	B	C	D	E	Weight (kg)
250	250	300	2	25	165	2
315	315	375	2	30	165	4
400	400	490	2	45	165	5
500	500	600	2.5	50	165	7
560	560	680	3	50	165	10
630	630	730	3	50	165	12
710	710	810	3	50	165	13
800	800	900	4	50	200	18
1000	1000	1120	4	60	200	25

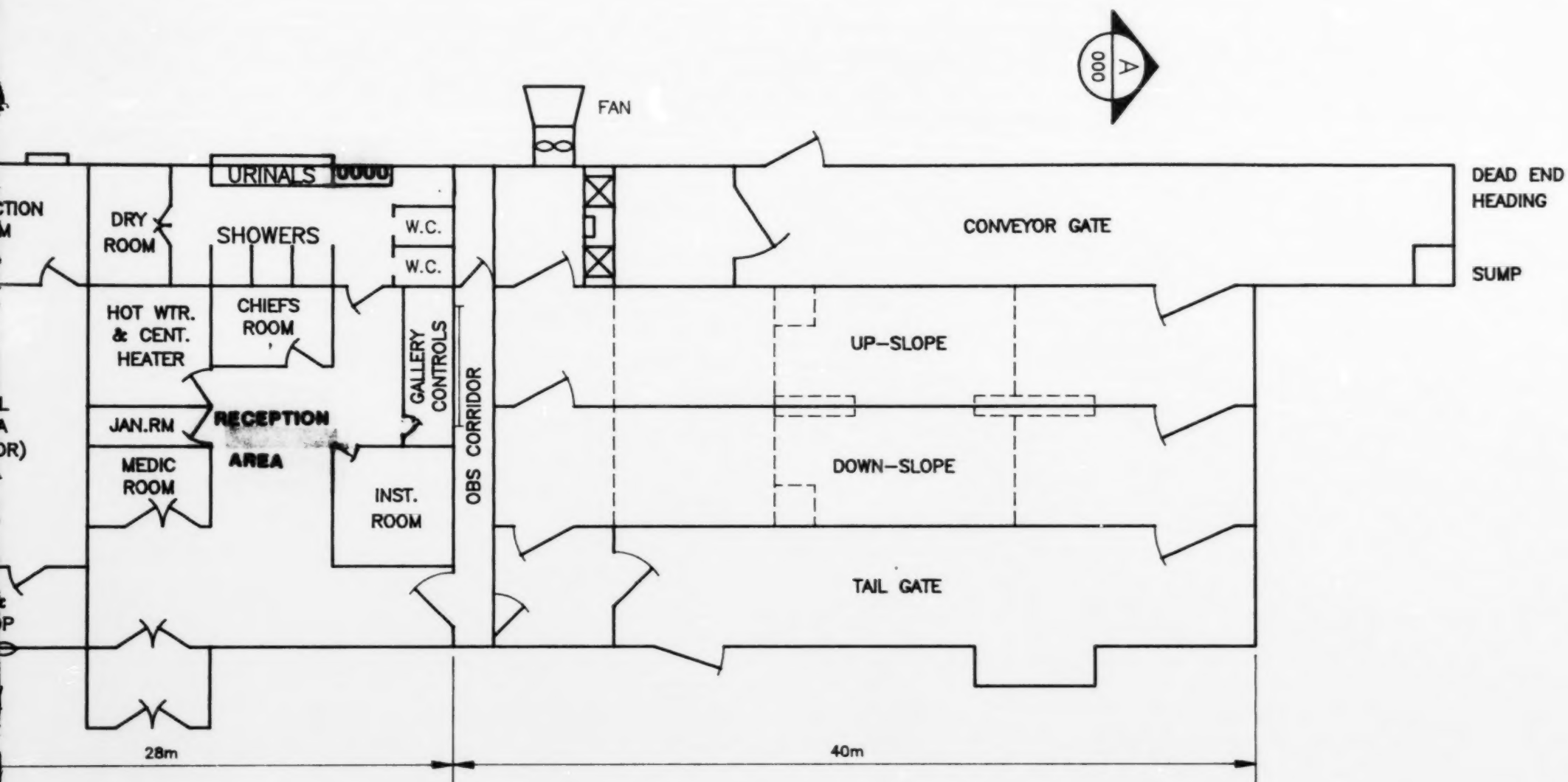
ALL DIMENSIONS IN MILLIMETRES.

Table 7. Matching Flanges and Flexible Connection - Sizes and Weights

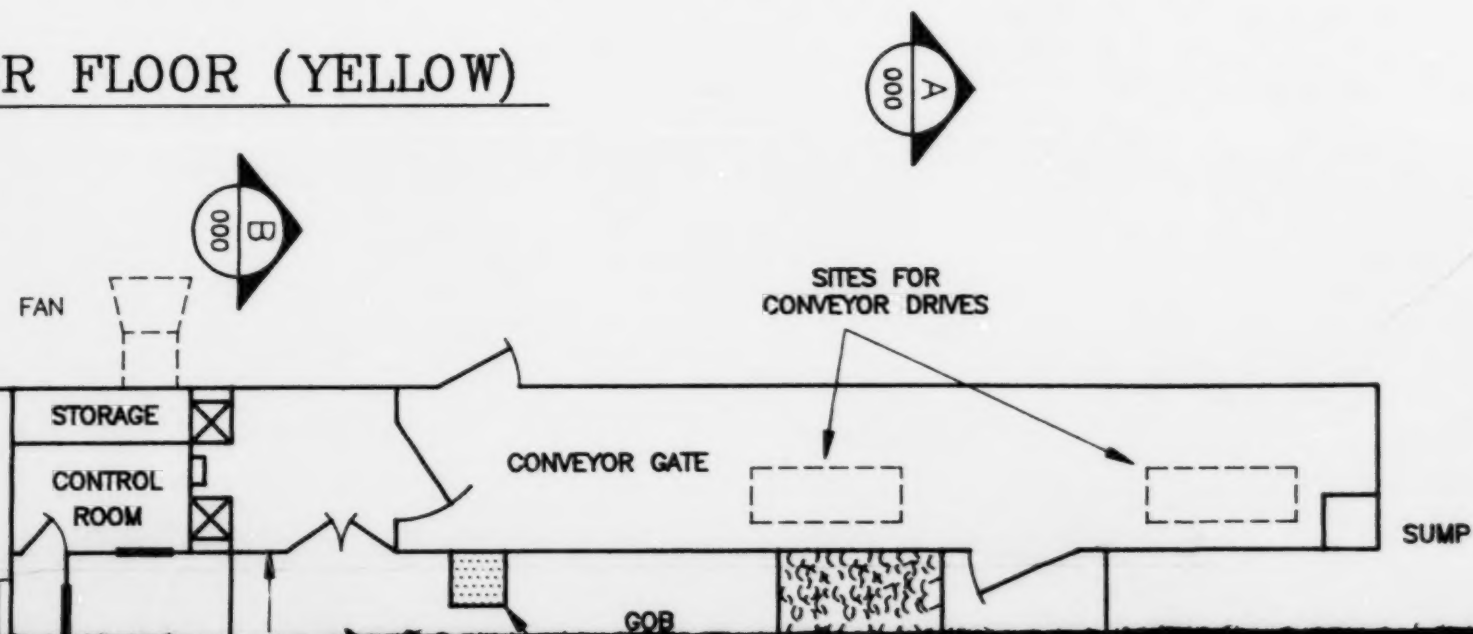


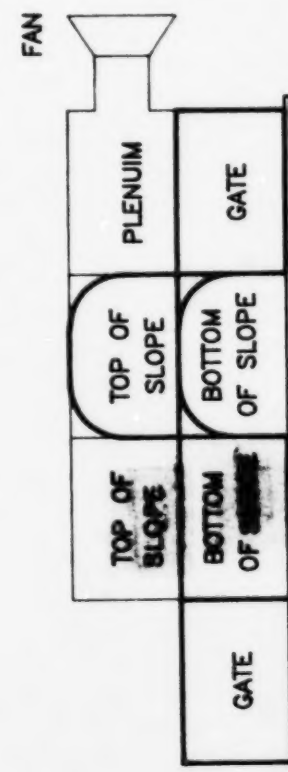
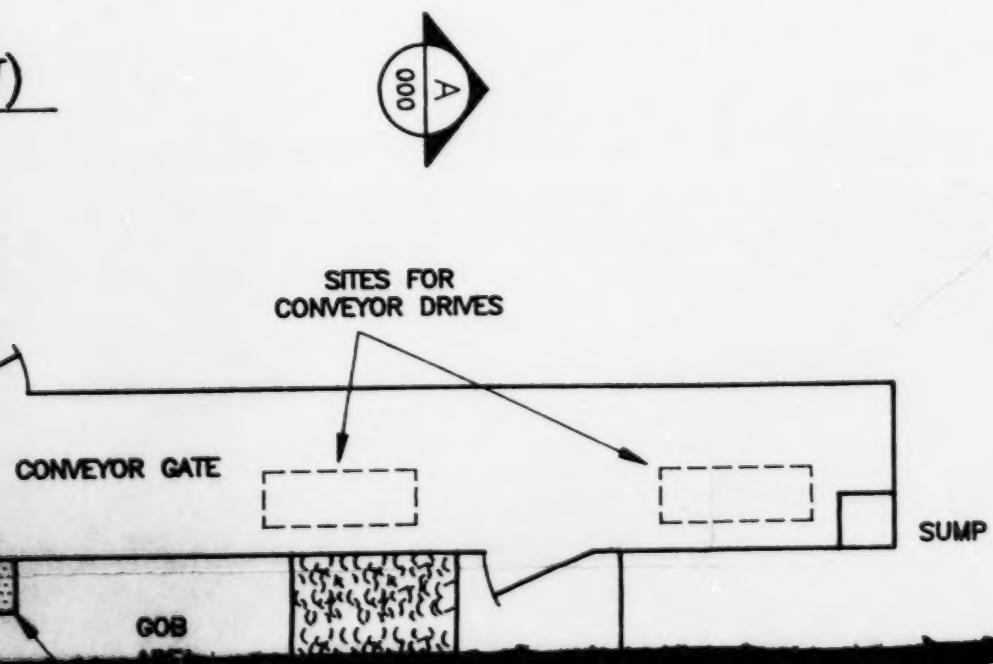
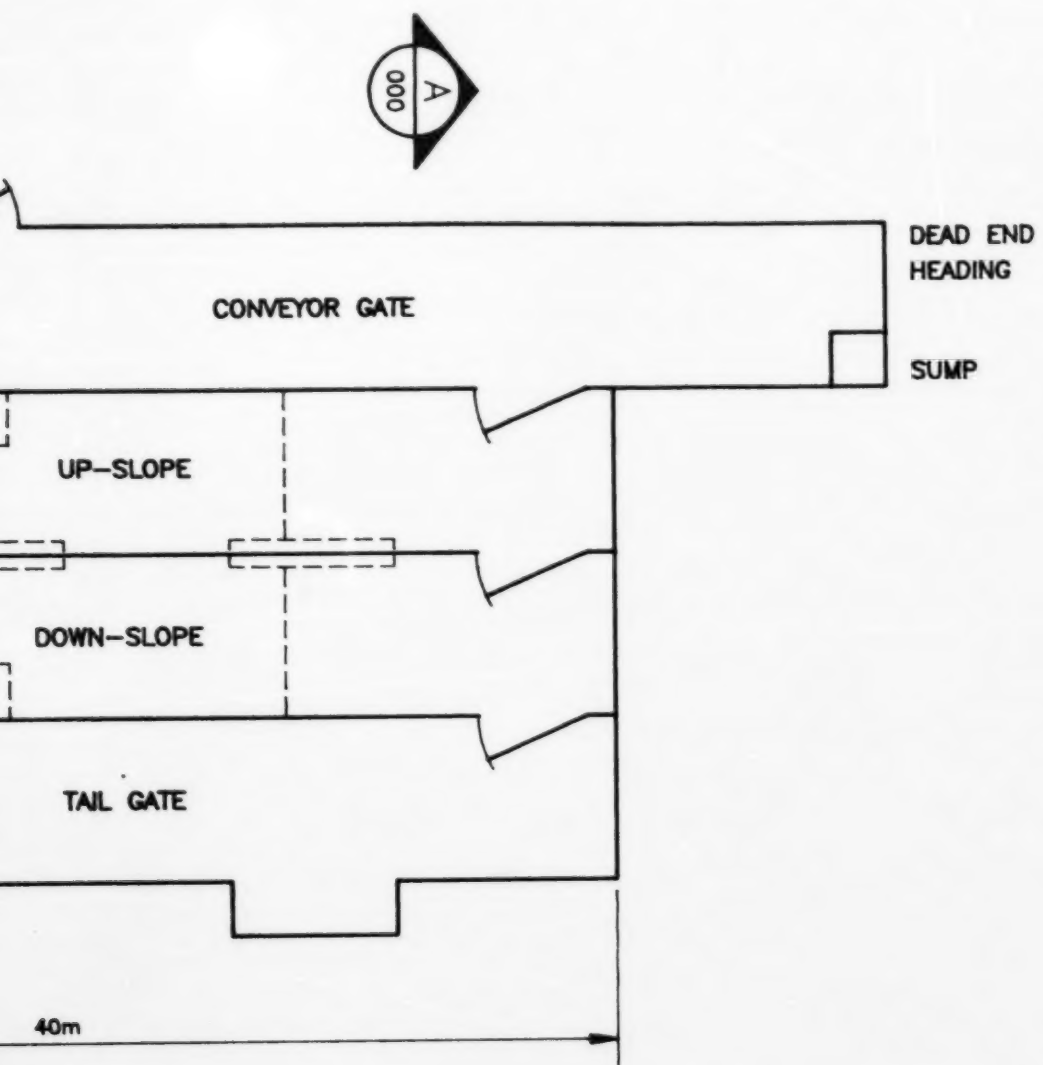
FLOOR PLAN - UPPER FLOOR (YELLOW)



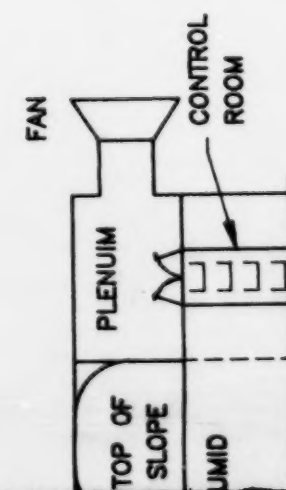


FLOOR PLAN - UPPER FLOOR (YELLOW)

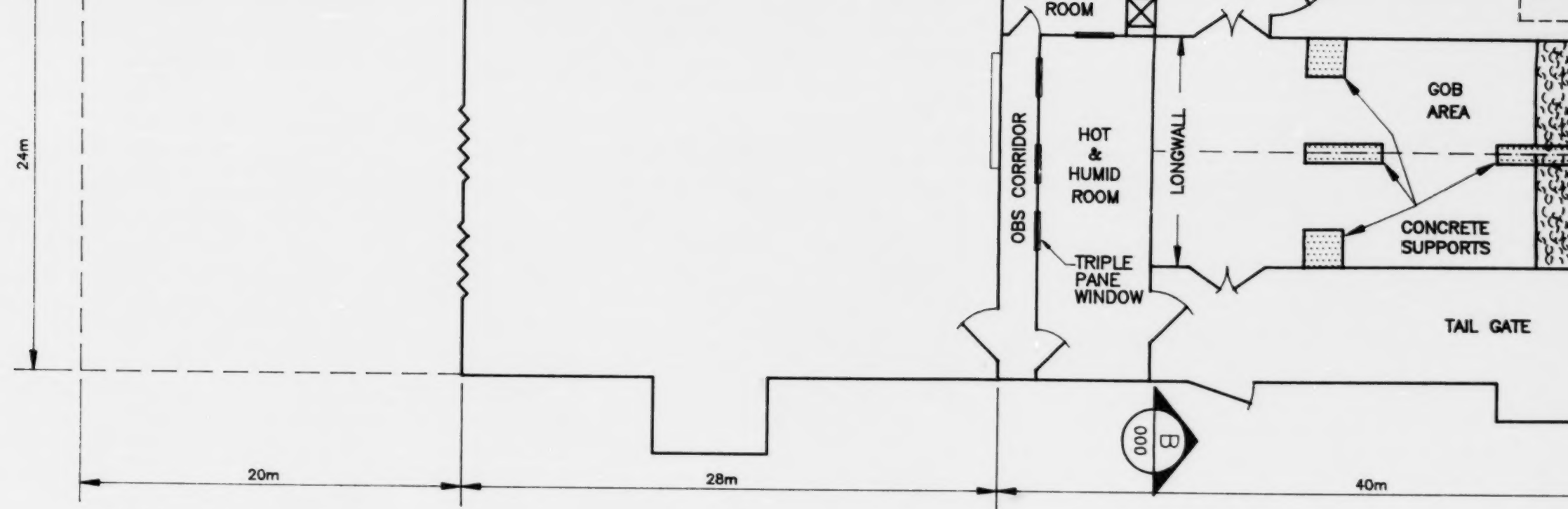




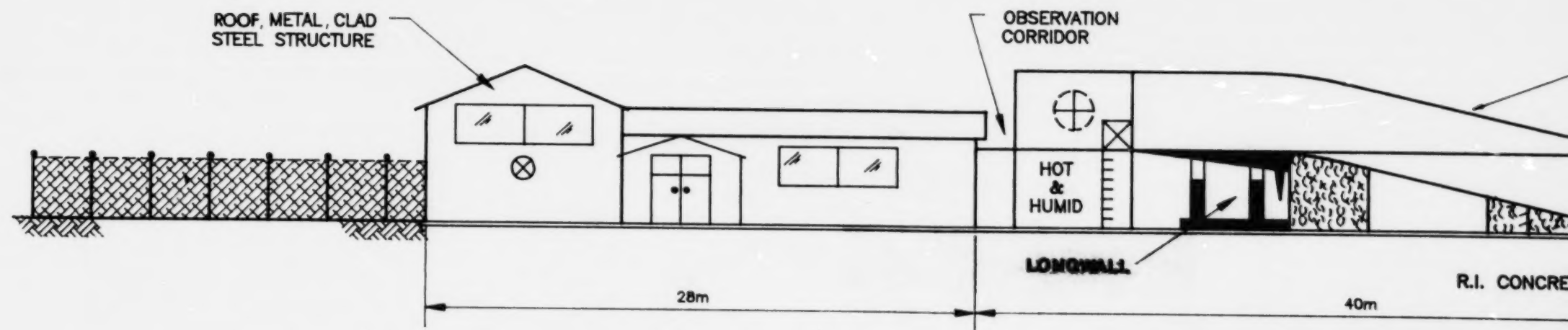
SECTION A - A



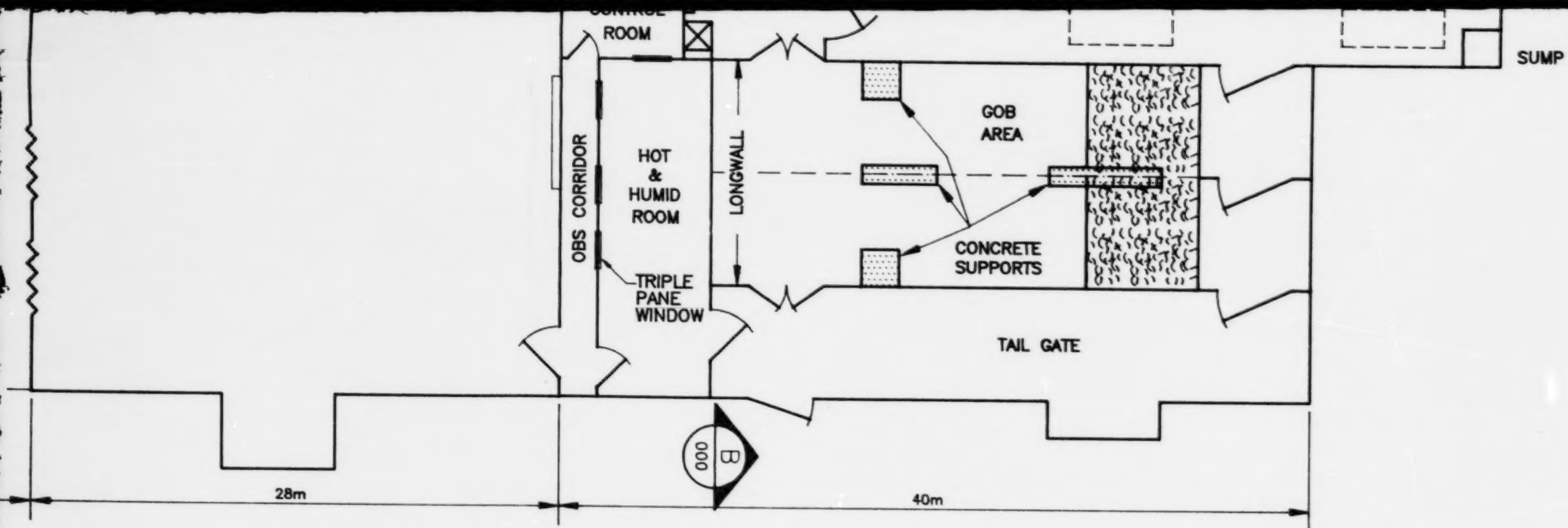
- B'



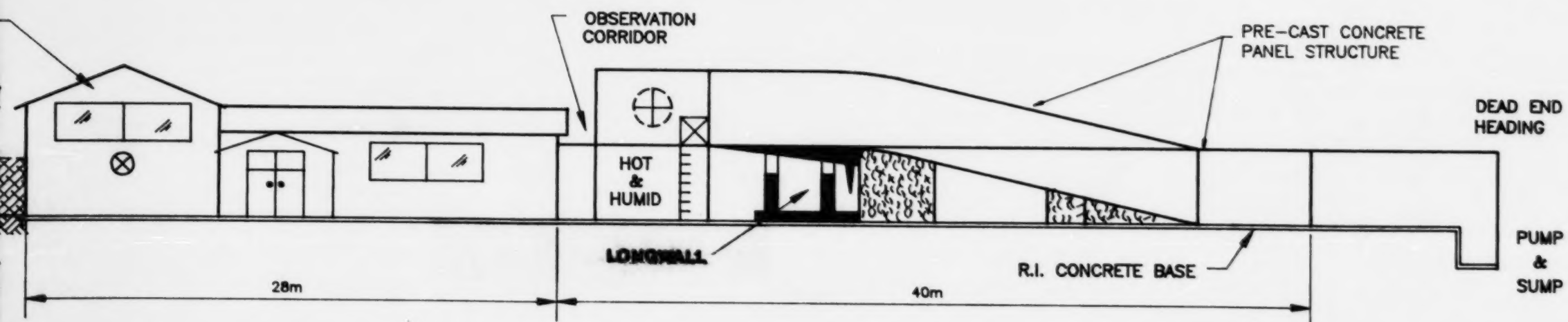
FLOOR PLAN - GROUND FLOOR



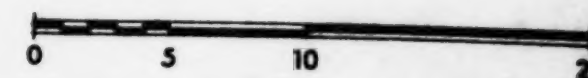
ELEVATION



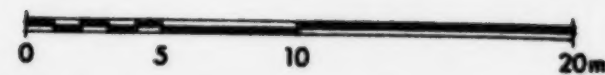
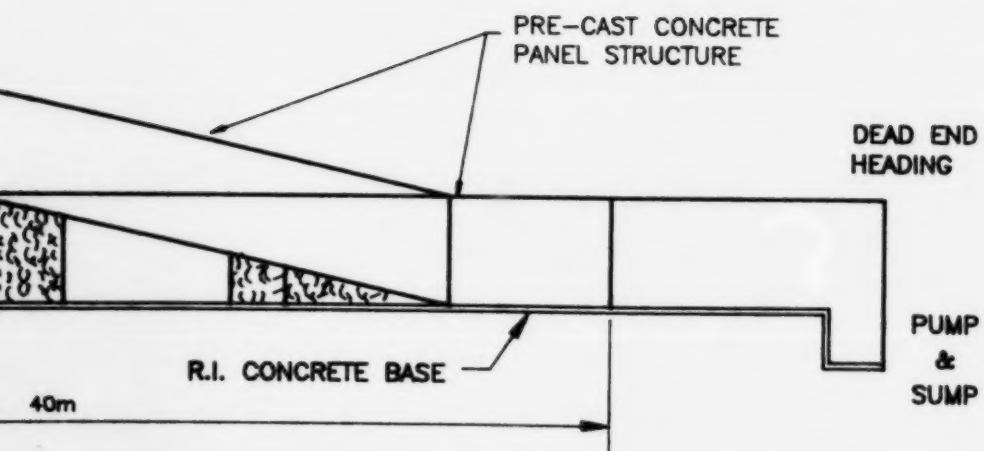
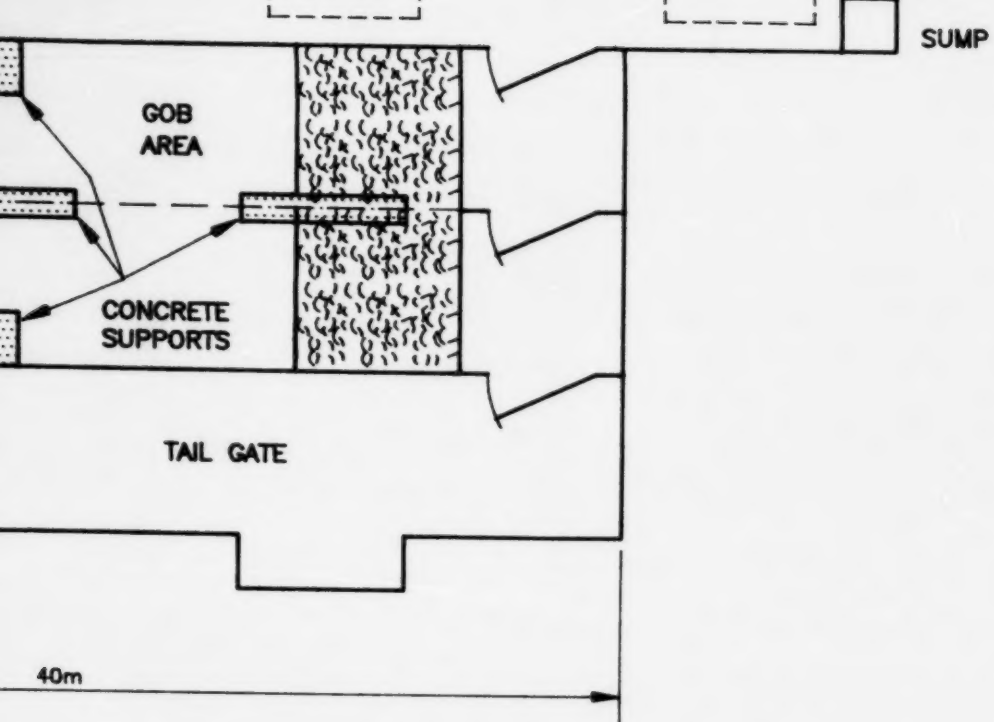
FLOOR PLAN - GROUND FLOOR



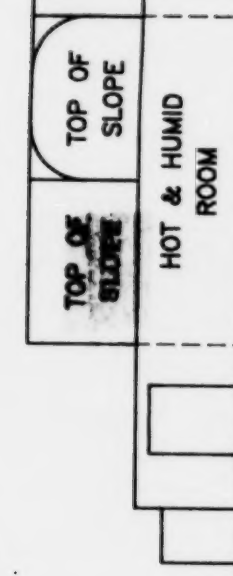
ELEVATION



SCALE 1 : 250



SCALE 1:250



SECTION B - B'

NorWest
Mine Services Ltd.

PROPOSED FIRE-FIGHTING
TRAINING GALLERY - PHALEN SITE

DATE
APRIL 1988
CADFILE 707-01

FILE No.

FIG. 5-1

REV.